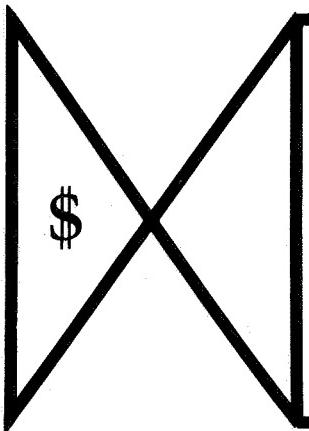


AT&T 67399

N73-20902

SPACE TUG
ECONOMIC
ANALYSIS STUDY

NAS 8-27709



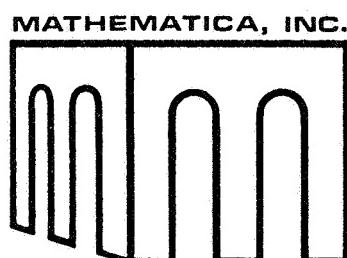
FINAL REPORT
DR MA-04
**CASE FILE
COPY.**

VOLUME II: TUG CONCEPTS ANALYSIS

APPENDIX – TUG DESIGN & PERFORMANCE DATA BASE

Prepared for
National Aeronautics & Space Administration
George C. Marshall Space Flight Center

Lockheed Missiles & Space Company, Inc.
Sunnyvale, California
and
Mathematica Inc.
Princeton, New Jersey



SPACE TUG
ECONOMIC ANALYSIS STUDY

FINAL REPORT

DR MA-04

May 1972

VOLUME II: TUG CONCEPTS ANALYSIS

Appendix: Tug Design and Performance Data Base

Prepared For

National Aeronautics and Space Administration

Marshall Space Flight Center

Prepared By

Lockheed Missiles & Space Company, Inc.,

Sunnyvale, California

and

Mathematica, Inc.

Princeton, New Jersey

CONTENTS

Chapter		Page
	FOREWORD	ii
1	INTRODUCTION	1-1
2	REUSABLE TUG DESIGN DATA	2-1
3	PERFORMANCE DATA	3-1

TABLES

2-1	Roadmap of Design Data in Chapter 2	2-2
3-1	Roadmap of Tug Performance Data in Chapter 3	3-2

FOREWORD

This report summarizes work accomplished under the Space Tug Economic Analysis Study on Contract NAS8-27709. This study was performed for the NASA Marshall Space Flight Center by Lockheed Missiles & Space Company, Inc. of Sunnyvale, California, and Mathematica, Inc. of Princeton, New Jersey. The period of technical performance was nine months, starting July 26, 1971.

The NASA Contracting Officer's Representatives for this program were Lieutenant Commander William C. Stilwell (USN) and Mr. Richard L. Klan. The study team was led by Mr. Charles V. Hopkins of Lockheed and Dr. Edward Greenblat of Mathematica. Task leaders on the Lockheed team were as follows:

John P. Skratt	- Data Integration and Interpretation
William T. Eaton	- Payload Data and Payload Effects Analysis
Richard T. Parmley	- Tug Definition

Other key team members included:

Anthony G. Tuffo	- Data Mechanization and Evaluation
Zoe A. Taulbee	- Computer Programming
Jolanta B. Forsyth	- Payload Costs and Benefits; Tug Cost Model
Kenneth J. Lush	- Program Costing Logic

This report is organized as follows:

- Volume I - Executive Summary
- Volume II - Tug Concepts Analysis
 - Part 1: Overall Approach and Data Generation
 - Part 2: Economic Analysis
 - Appendix: Tug Design and Performance Data Base
- Volume III - Cost Estimates

Volume II contains detailed discussions of the methods used to perform this study, and the major findings that have resulted. For convenience Volume II has been further divided into three parts. This Appendix supplements the results presented in the first two parts by documenting the detailed Tug design and performance information that forms part of the Tug data base.

Chapter 1 INTRODUCTION

A sizeable data base of Space Tug vehicle characteristics, costs, and performance capabilities was generated as a basis from which to compare concepts on this study. This Appendix to Volume II is a compendium of the detailed design and performance information from the data base. Comparable cost data are incorporated into a separate volume as specified in Data Requirement Description number MA-04; the cost volume is Volume III of the final report.

The design data are parametric across a range of reusable Space Tug sizes, whereas the performance curves were generated for selected point designs of expendable orbit injection stages and reusable Tugs. The Appendix is divided into two principal chapters. Chapter 2 contains the design data and Chapter 3 presents the performance data.

Chapter 2

REUSABLE TUG DESIGN DATA

This chapter presents parametric design data on reusable ground-based Space Tug concepts developed during the study. As explained at length in Part 1 of Volume II, the reusable Tugs were defined using a set of design estimating relationships (DERs). These relationships, extrapolated from Lockheed-generated point designs for the Space Tug, take the form of equations that characterize vehicle dimensions and weights down to major assembly level; the equations relate Tug design concept and propellant weight and type to specific parameters of interest. The DERs are automated in the Lockheed Space Transportation Analysis Routine (STAR) computer program which synthesizes weight statements and dimensional data across a range of propellant loadings from 20,000 to 70,000 pounds.

Chapter 2 comprises graphs of key Tug parameters; these graphs were plotted directly by computer. Information is presented in a data book format with minimum text. The sequence of Tug concepts presented in this chapter is as follows:

- LO₂/LH₂ Single Stage
- LF₂/LH₂ Single Stage
- FLOX/CH₄ Single Stage
- LO₂/LH₂ Drop Tanks (for Stage-and-one-half configurations)

To help locate data in Chapter 2, a roadmap matrix of Tug concepts and design data has been generated. This matrix, presented as Table 2-1, lists the figure references for all design graphs in Chapter 2.

Table 2-1 ROADMAP OF DESIGN DATA IN CHAPTER 2
(All References to Figure Numbers)

	LO ₂ /LH ₂ Reusable	LF ₂ /LH ₂ Reusable	FLOX/CH ₄ Reusable	LO ₂ /LH ₂ Expendable	FLOX/CH ₄ Expendable	LO ₂ /LH ₂ Drop Tanks
Structures Weight	2-1	2-19	2-30	2-48	2-58	2-76
Thermal Protection System Weight	2-2	2-20	2-31	2-49	2-59	2-77
Propulsion System Weight	2-3	2-21	2-32	2-50	2-60	2-78
Avionics and Electrical-Power System Weights	2-4	2-22	2-33	2-51	2-61	N/A
Nonusable Fluid Weights	2-5	2-23	2-34	2-52	2-62	2-80
Nonimpulse Consumable Fluid Weights	2-6	2-24	2-35	2-53	2-63	N/A
Total Stage Burnout Weight	2-7	2-25	2-36	2-54	2-64	2-82
Tug Gross Weight	2-8	2-26	2-37	2-55	2-65	2-83
Mass Fraction Based on Gross Stage Weight	2-9	2-27	2-38	2-56	2-66	-
Mass Fraction Based on Burnout Weight and Impulse Propellant	2-10	2-28	2-39	2-57	2-67	2-85
Oxidizer Tank Dimensions	2-11	2-11	2-40	2-40	2-68	2-68
Oxidizer Tank Volume	2-12	2-12	2-41	2-41	2-69	2-69
Oxidizer Tank Area	2-13	2-13	2-42	2-42	2-70	2-70
Fuel Tank Dimensions	2-14	2-14	2-43	2-43	2-71	2-71
Fuel Tank Volume	2-15	2-15	2-44	2-44	2-72	2-72
Fuel Tank Area	2-16	2-16	2-45	2-45	2-73	2-73
Stage External Surface Area	2-17	2-29	2-46	2-46	2-74	-
Stage Overall Length	2-18	2-18	2-47	2-47	2-75	2-75

STRUCTURE

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

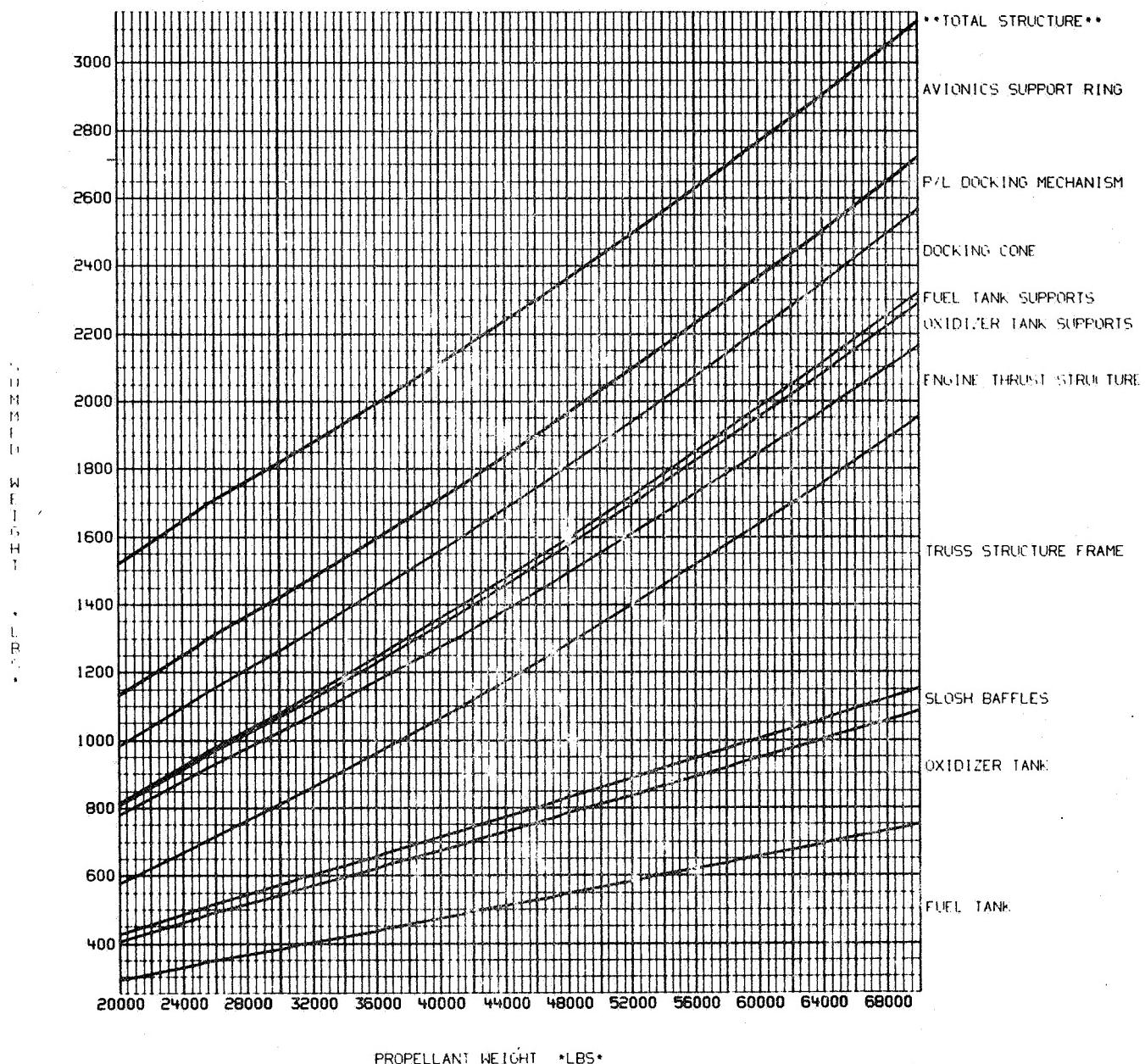


Figure 2-1

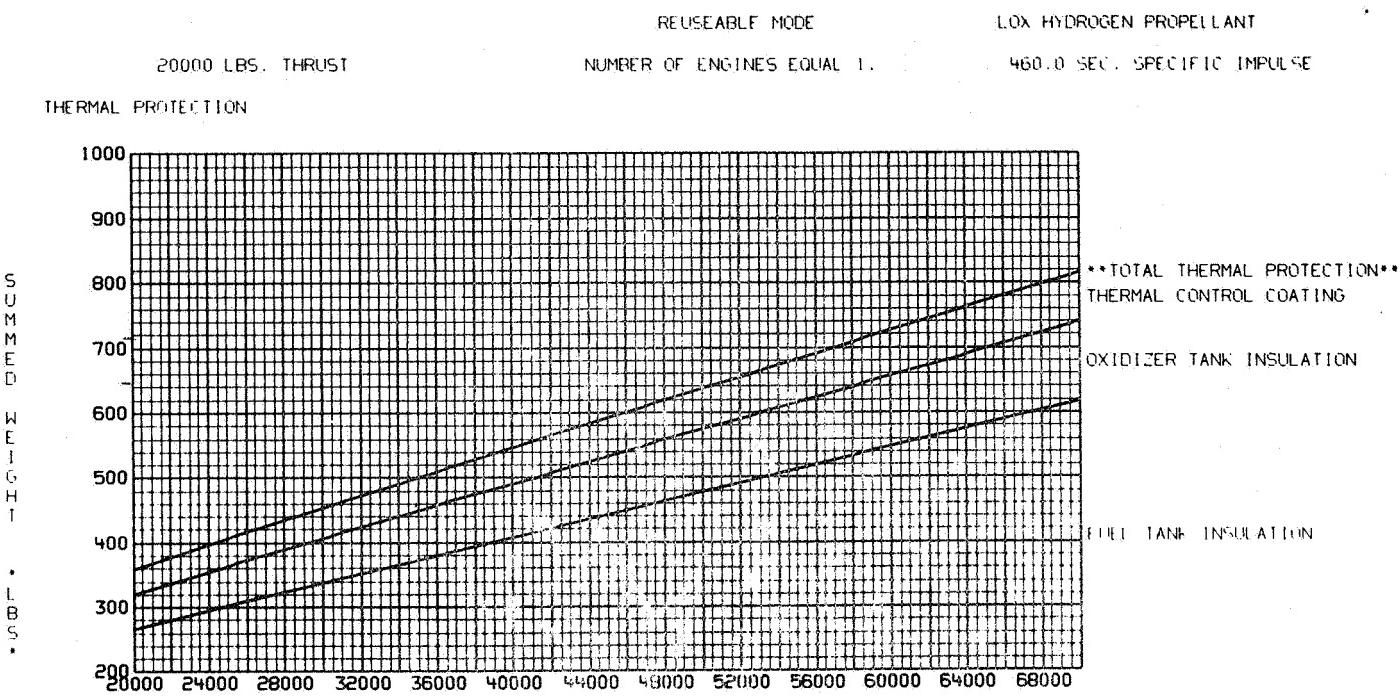


Figure 2-2

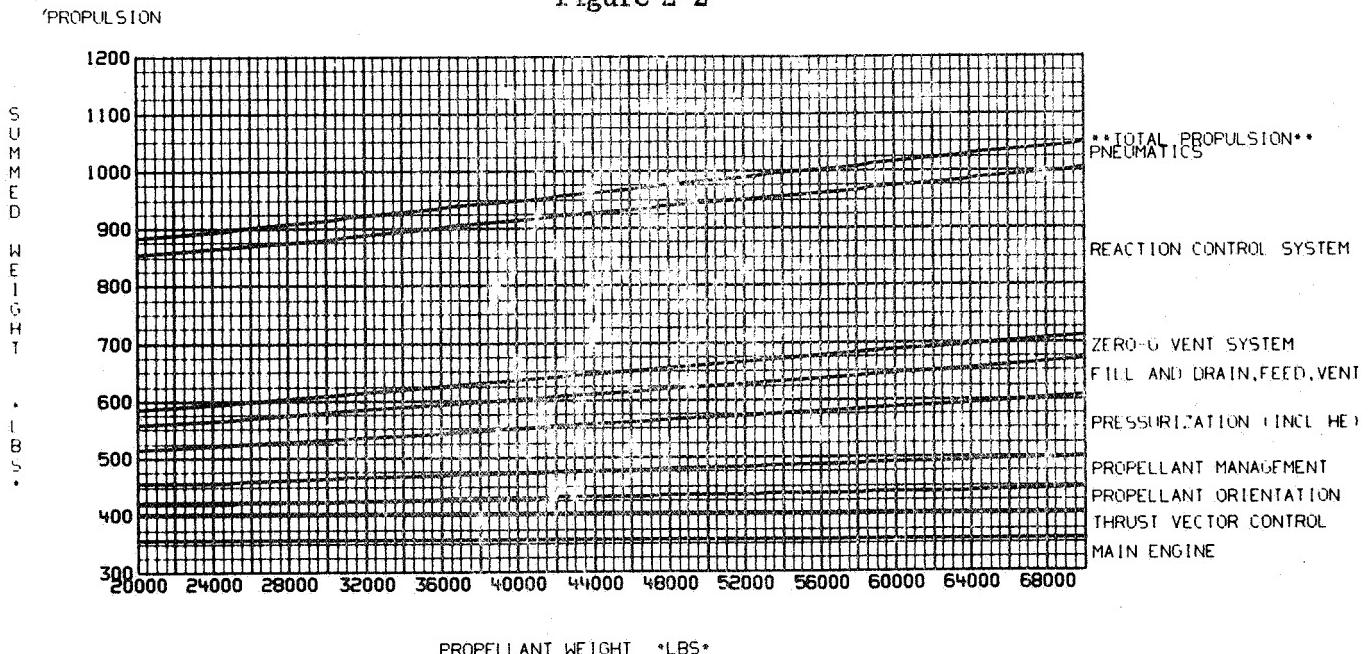


Figure 2-3

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

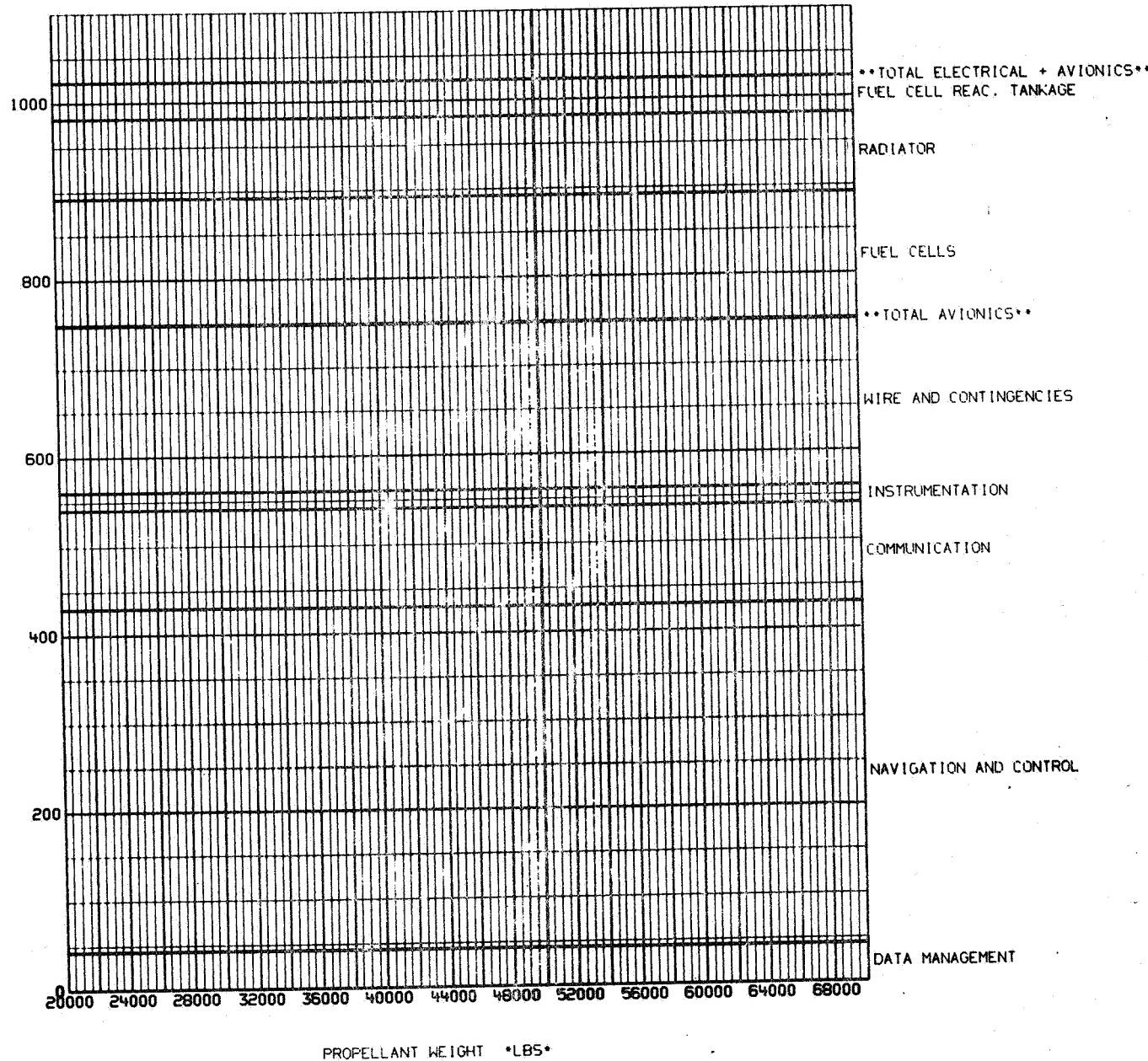
SUMMED
WEIGHT
• LBS •

Figure 2-4

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.
20000 LBS. THRUST
NON USEABLE FLUIDS

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

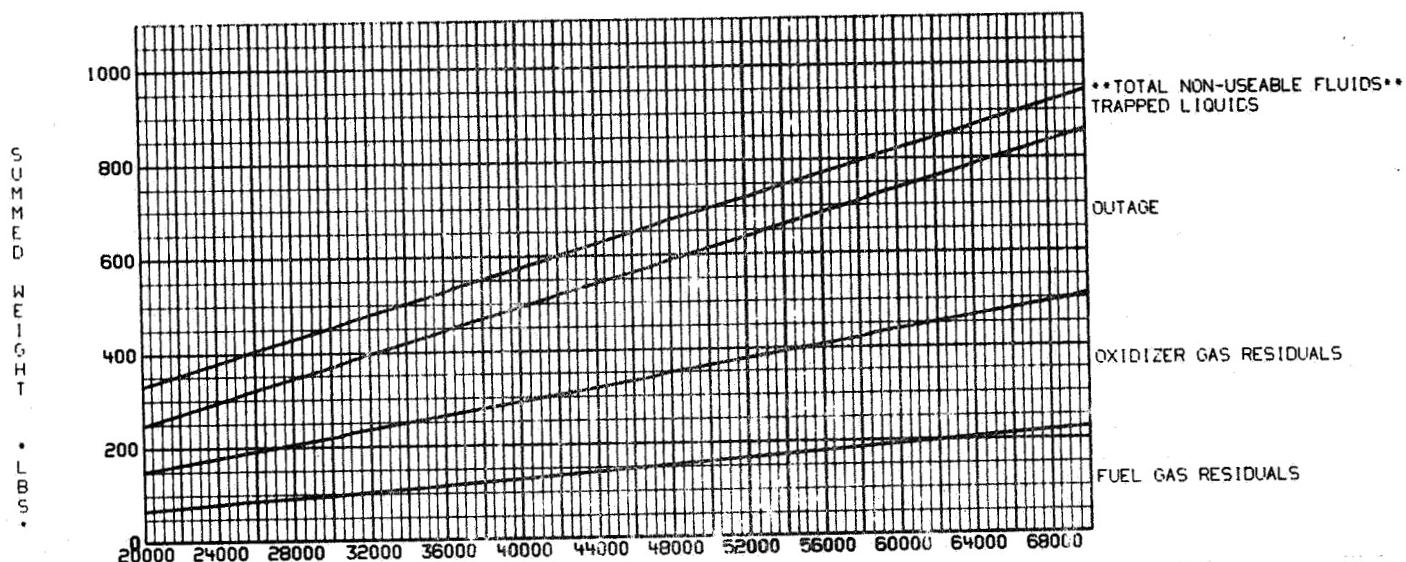


Figure 2-5

NON - IMPULSE CONSUMABLES

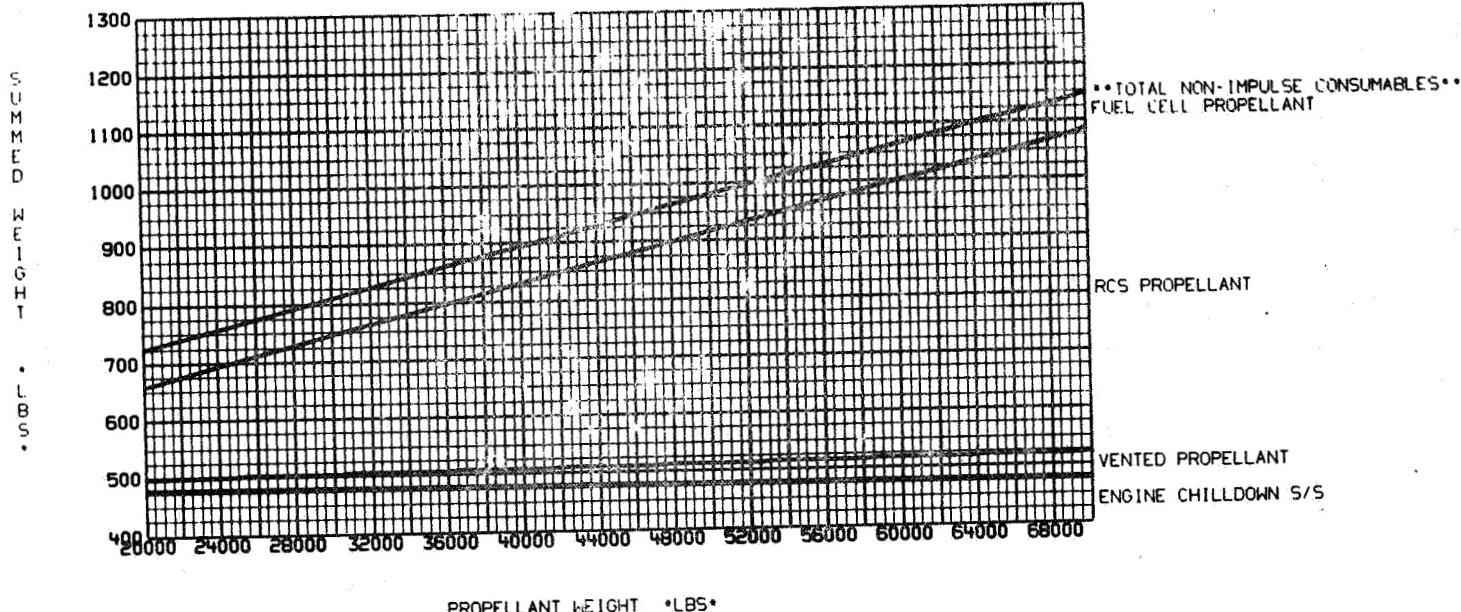


Figure 2-6

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

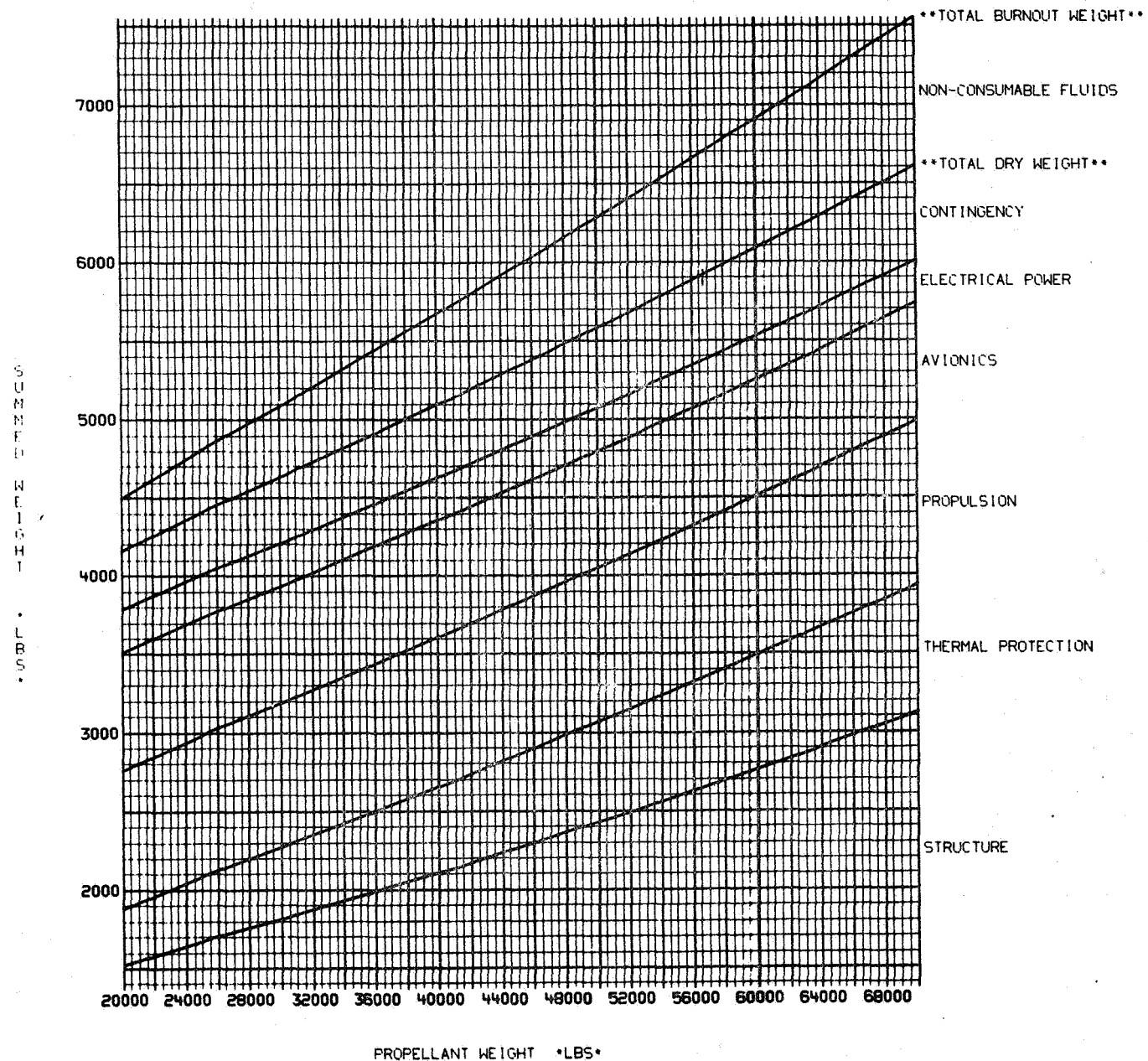


Figure 2-7

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

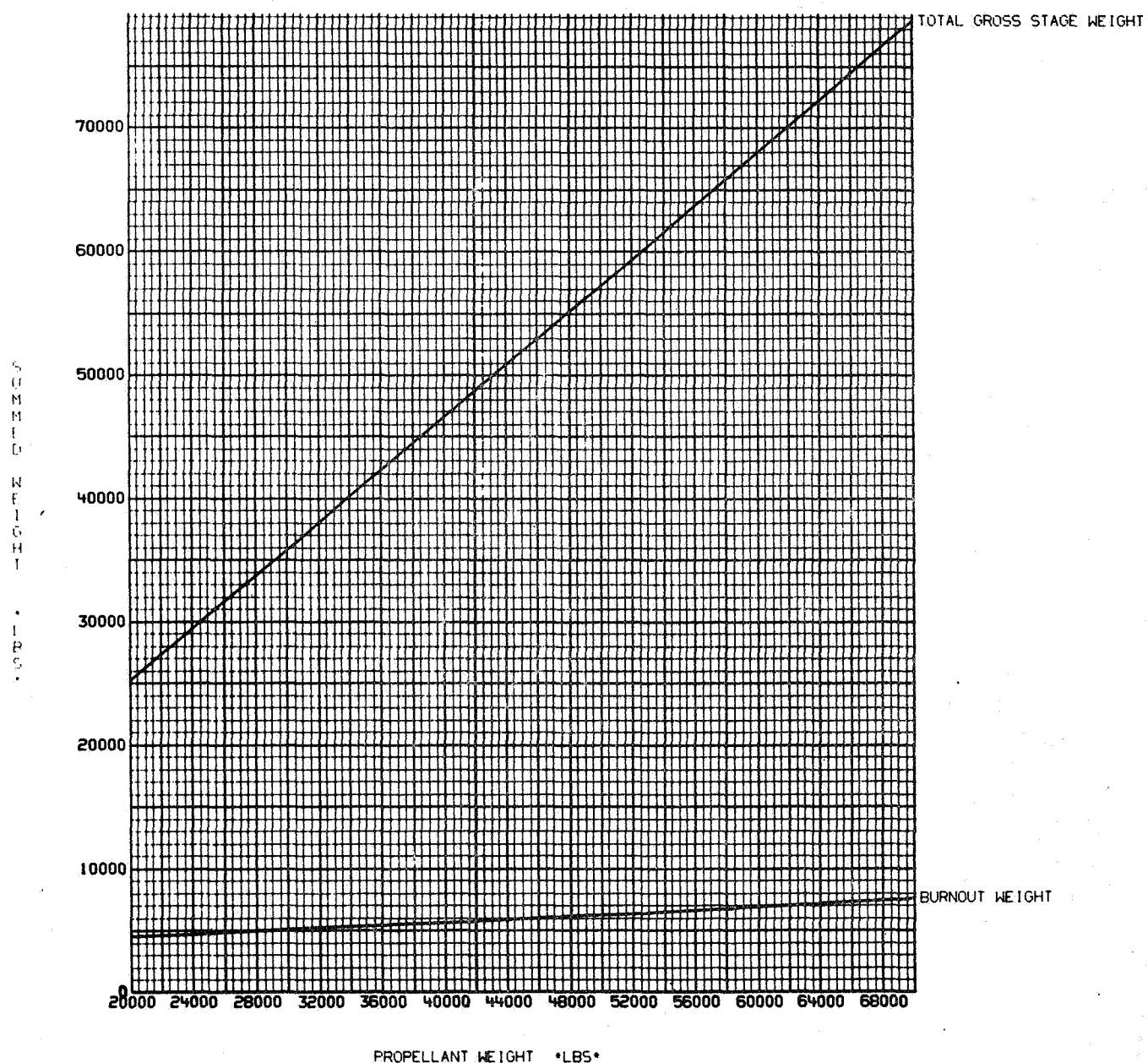


Figure 2-8

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

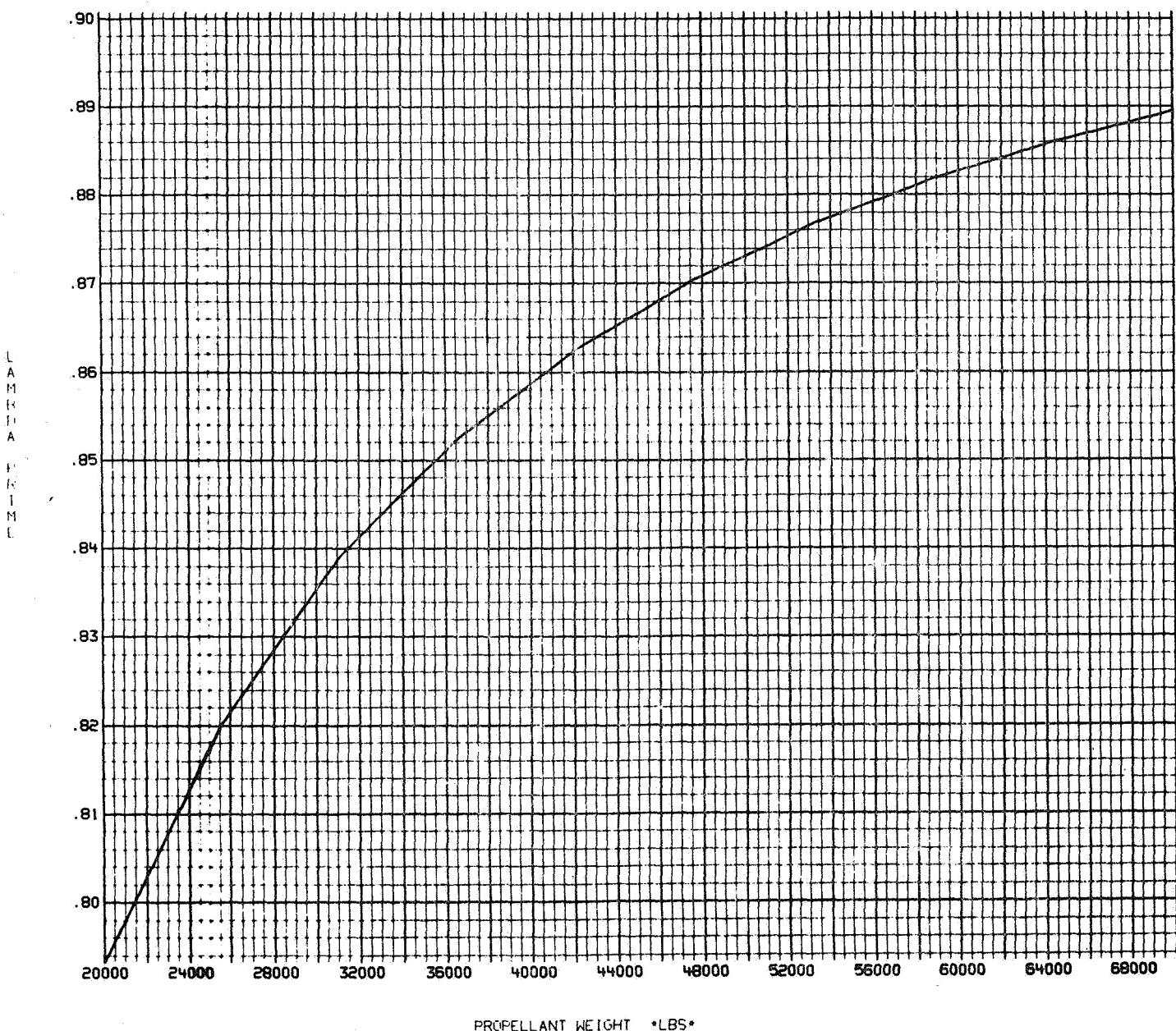


Figure 2-9

2-7

2-9

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

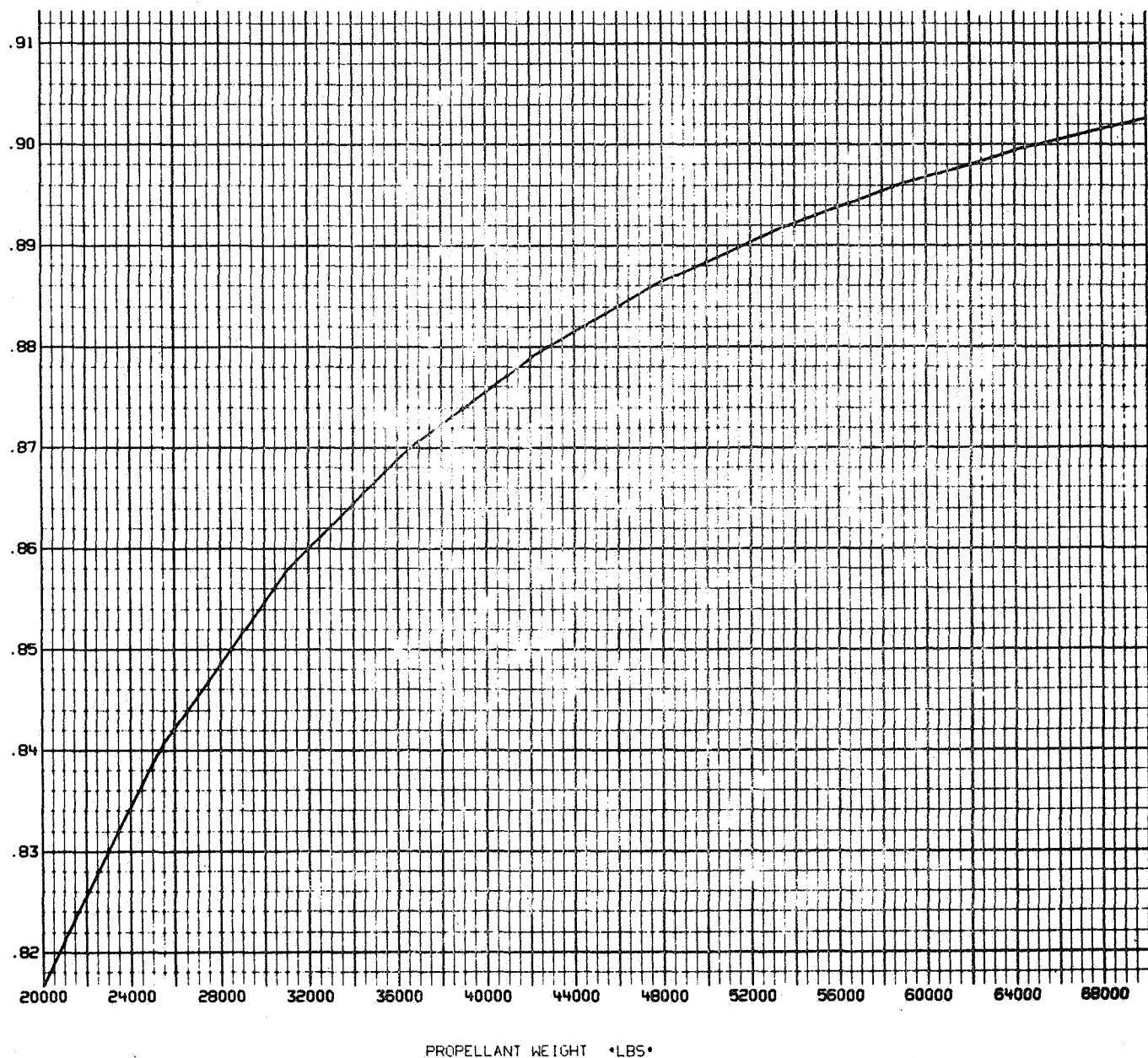


Figure 2-10

OXIDIZER TANK

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

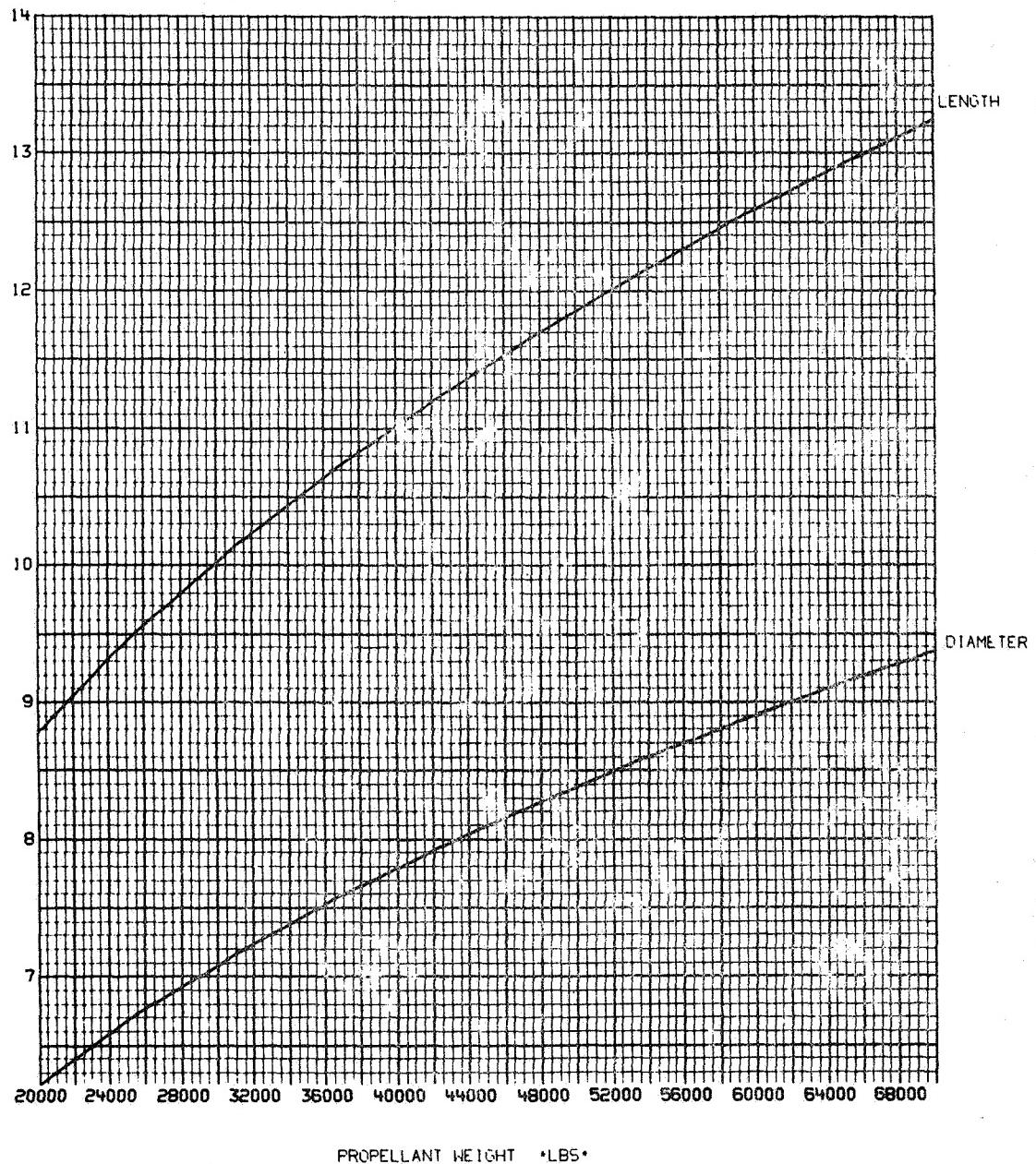


Figure 2-11

OXIDIZER TANK

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

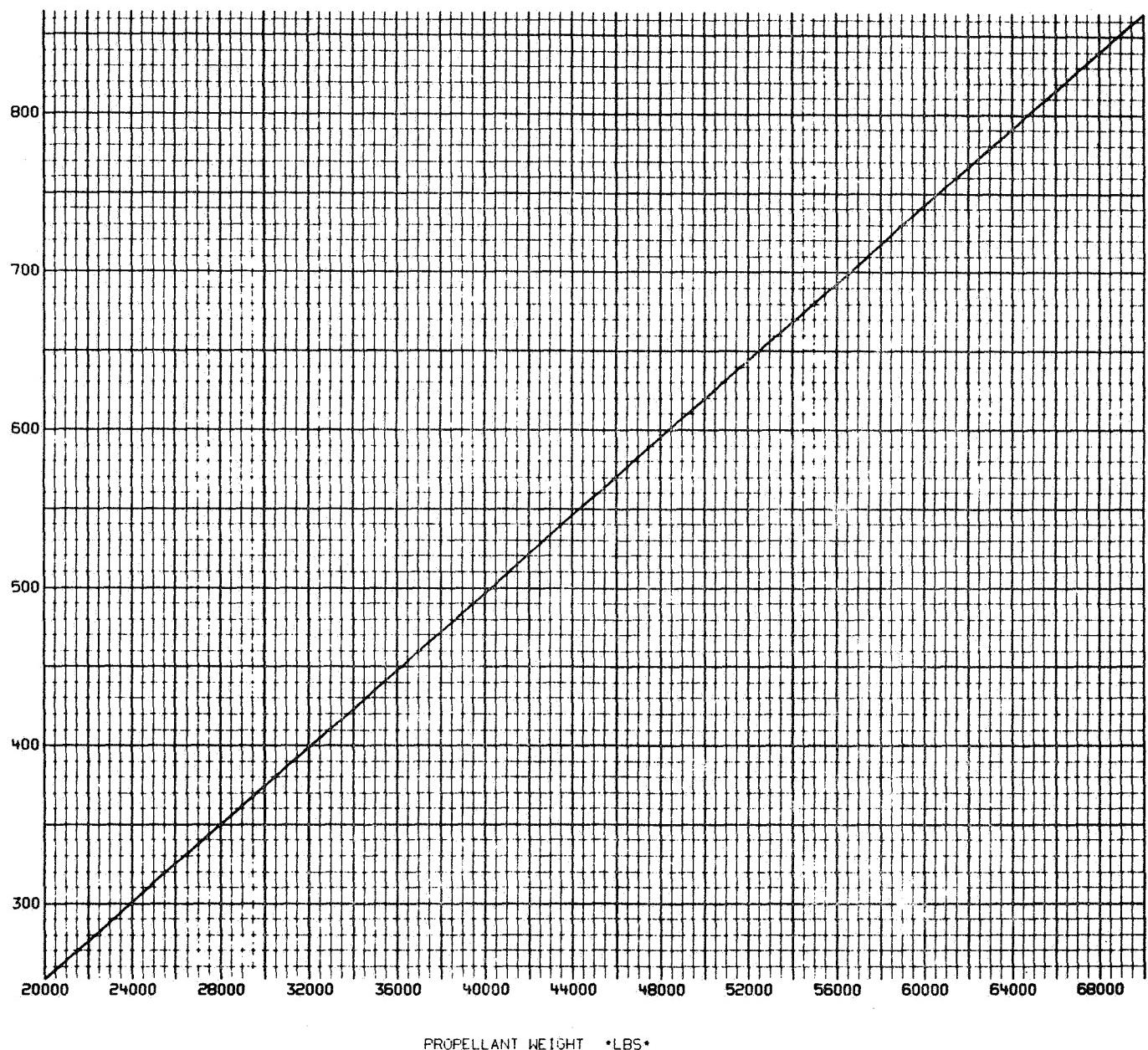


Figure 2-12

2-12

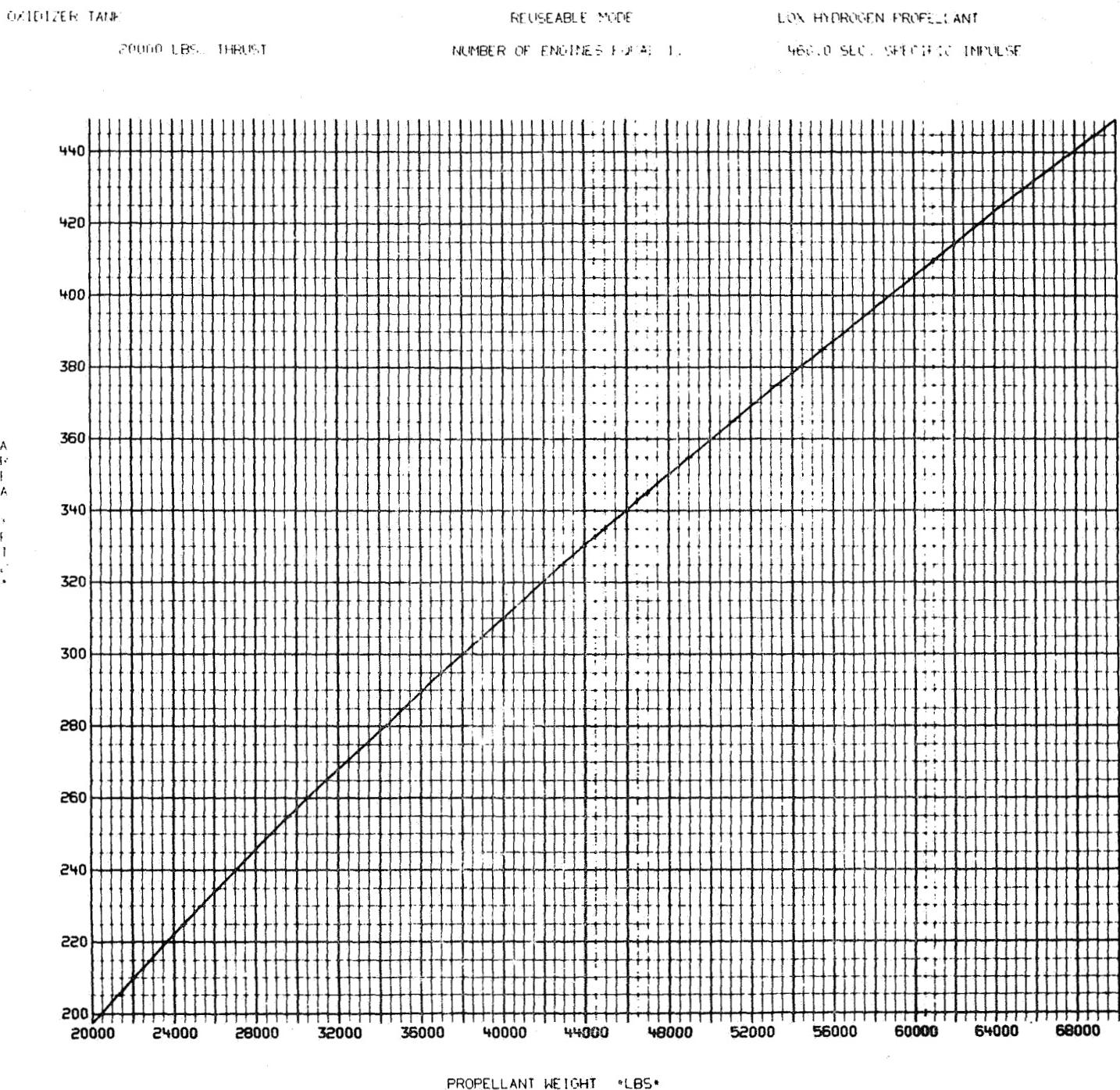


Figure 2-13

2-13

FUEL TANK

60000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

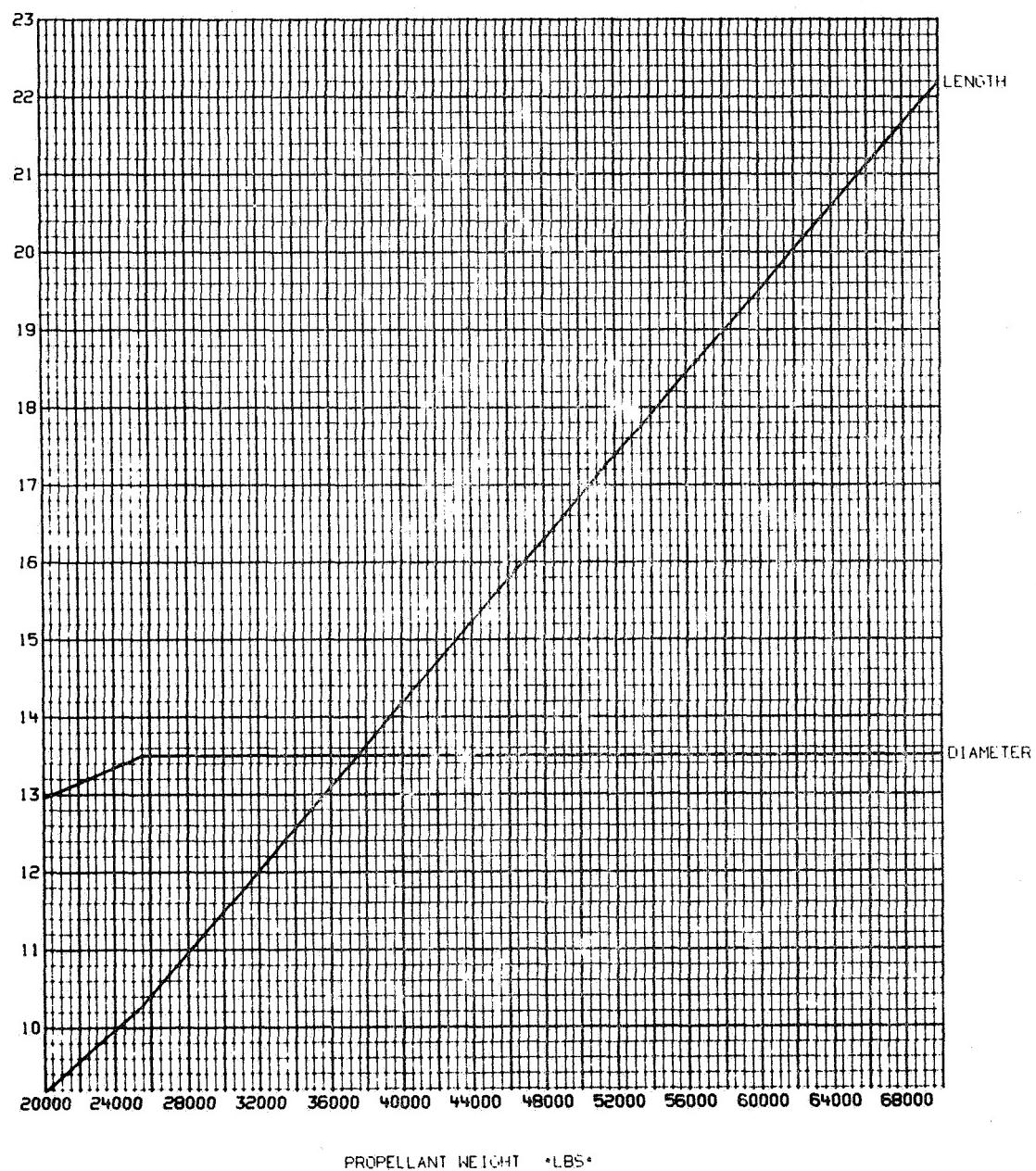


Figure 2-14

2-14

FUEL TANK

20000 LBS. THRUST

REUSABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

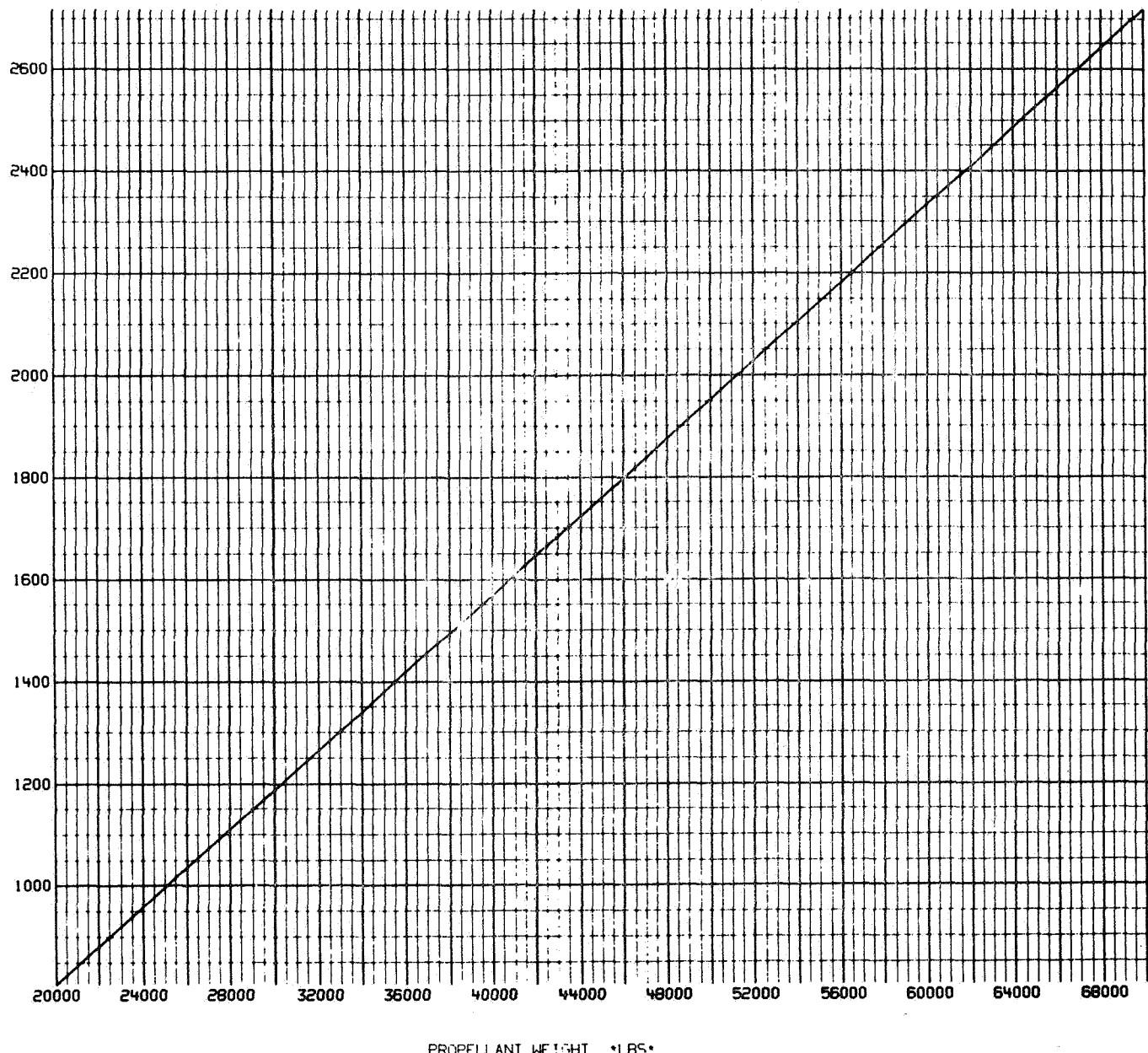


Figure 2-15

FUEL TANK

CONSTANT THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

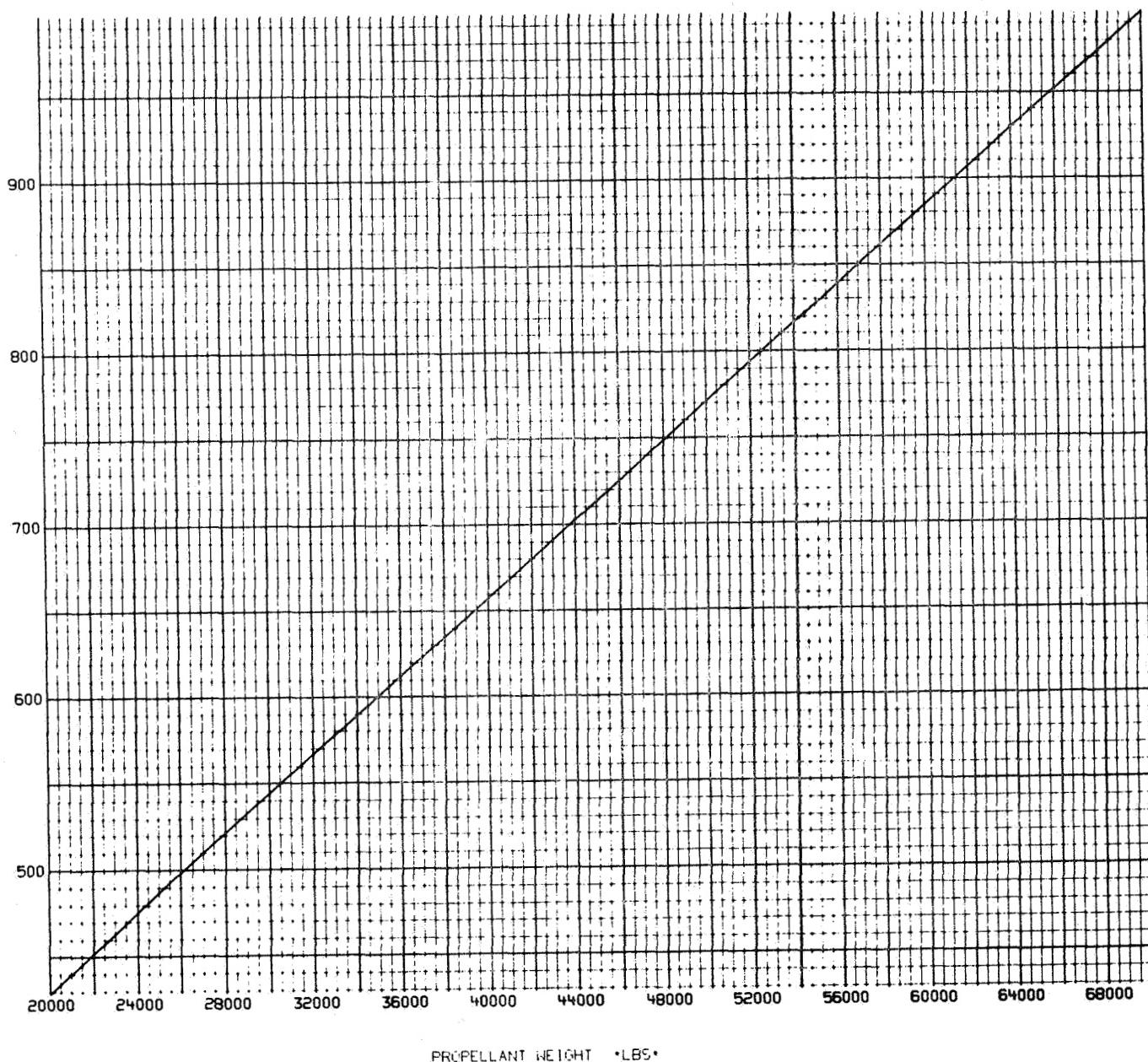


Figure 2-16

AREA OF CYLINDER + CONE

20000 LBS. THRUST

REUSABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

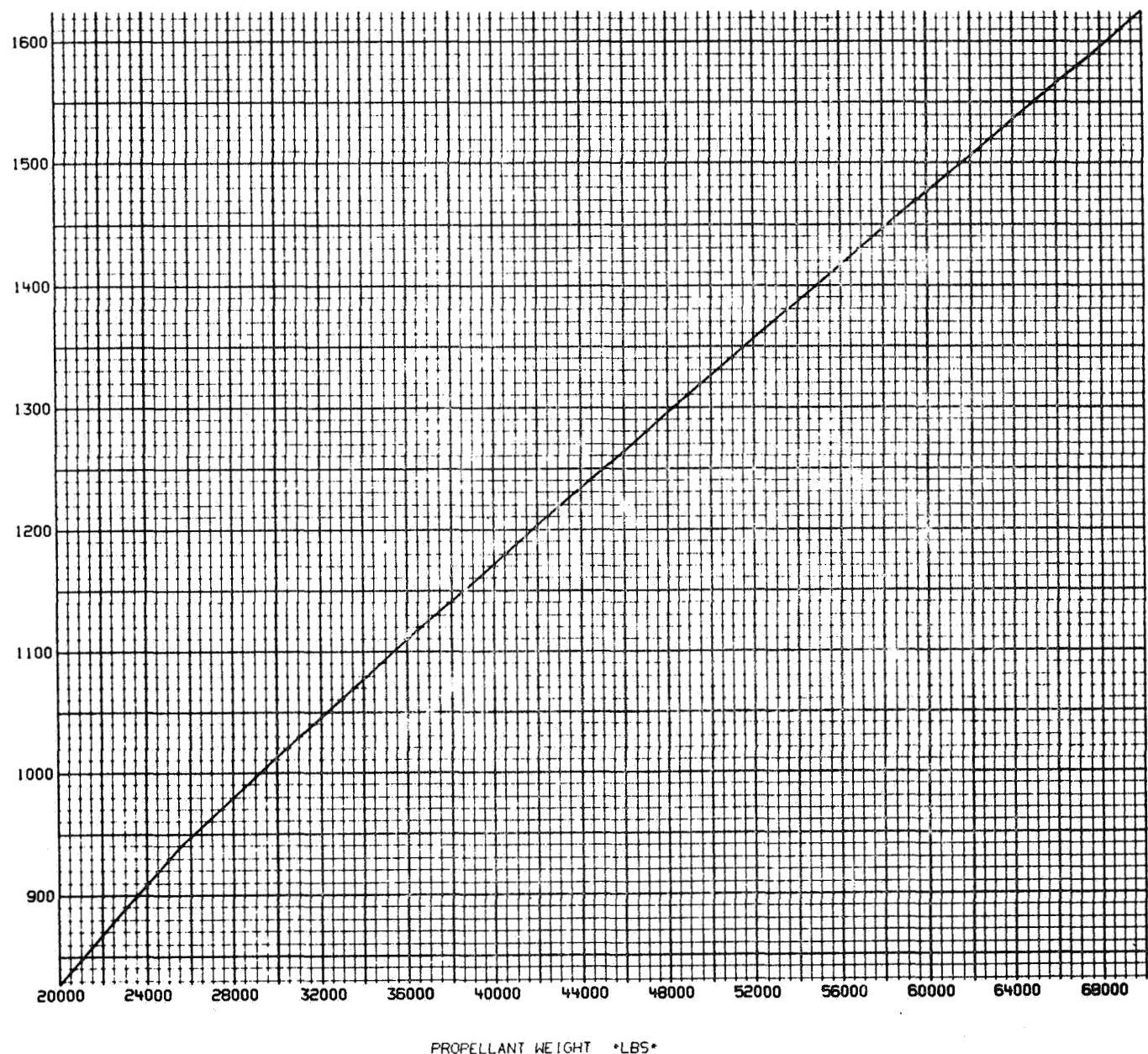


Figure 2-17

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

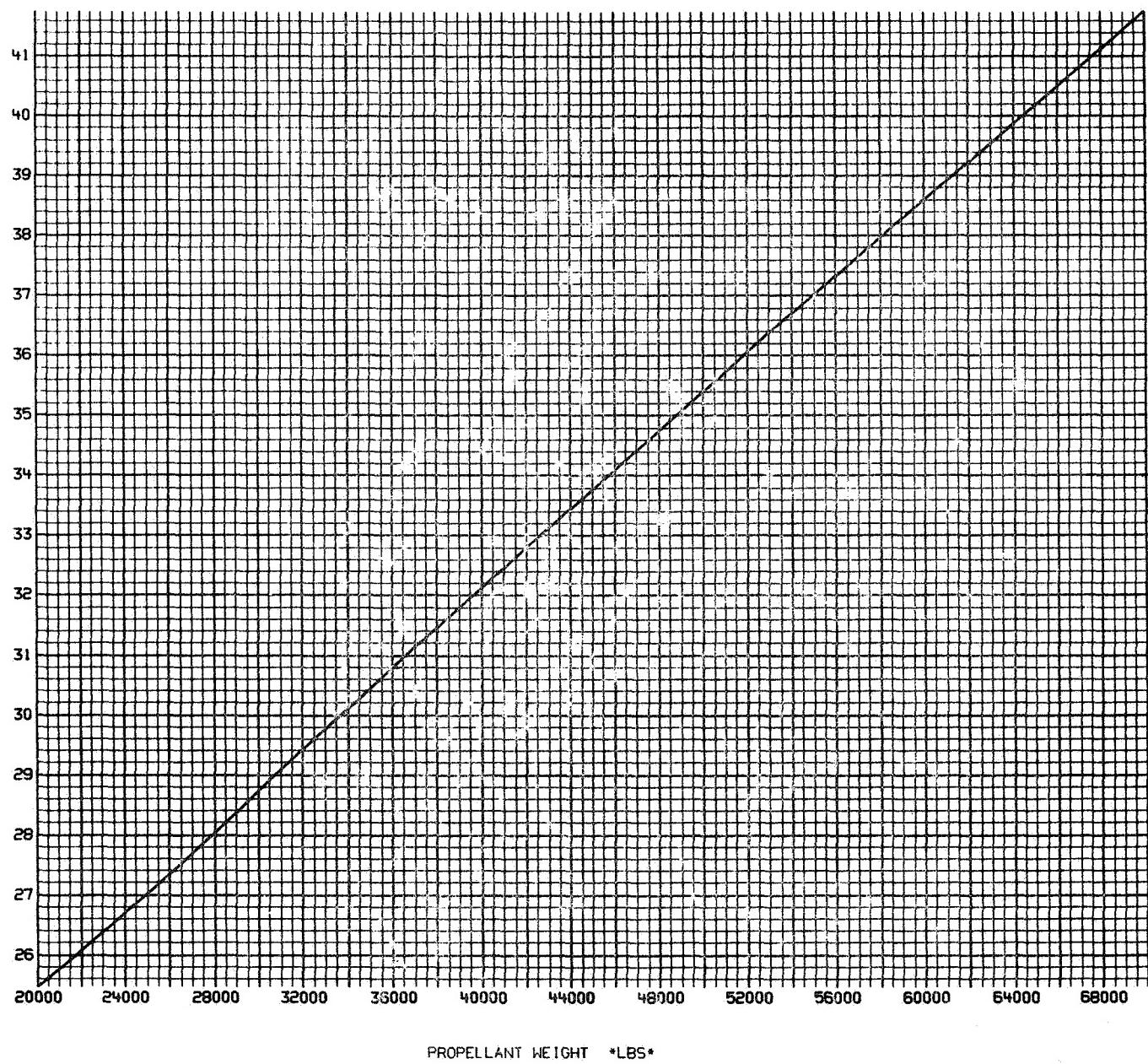


Figure 2-18

STRUCTURE

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

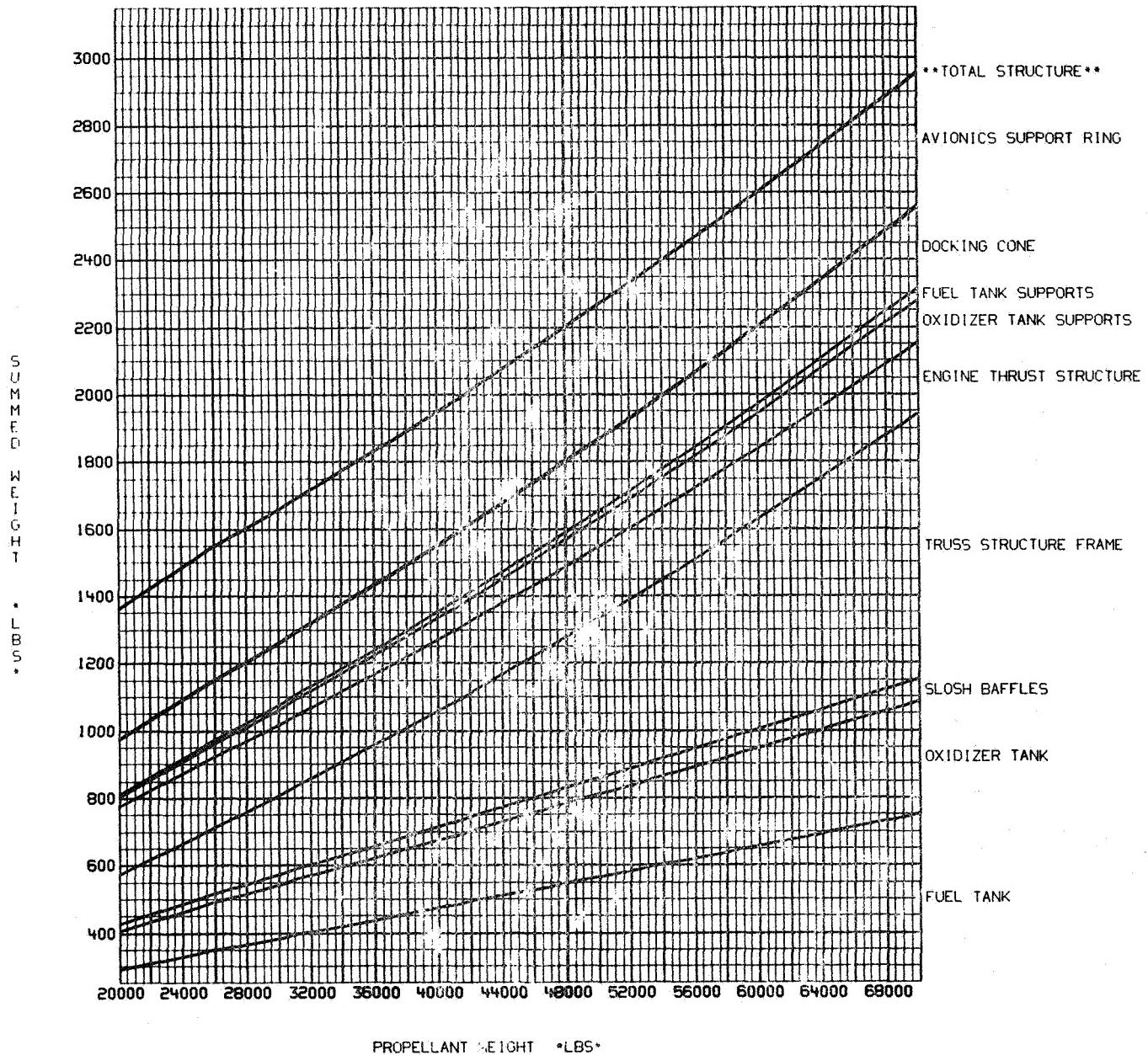


Figure 2-19

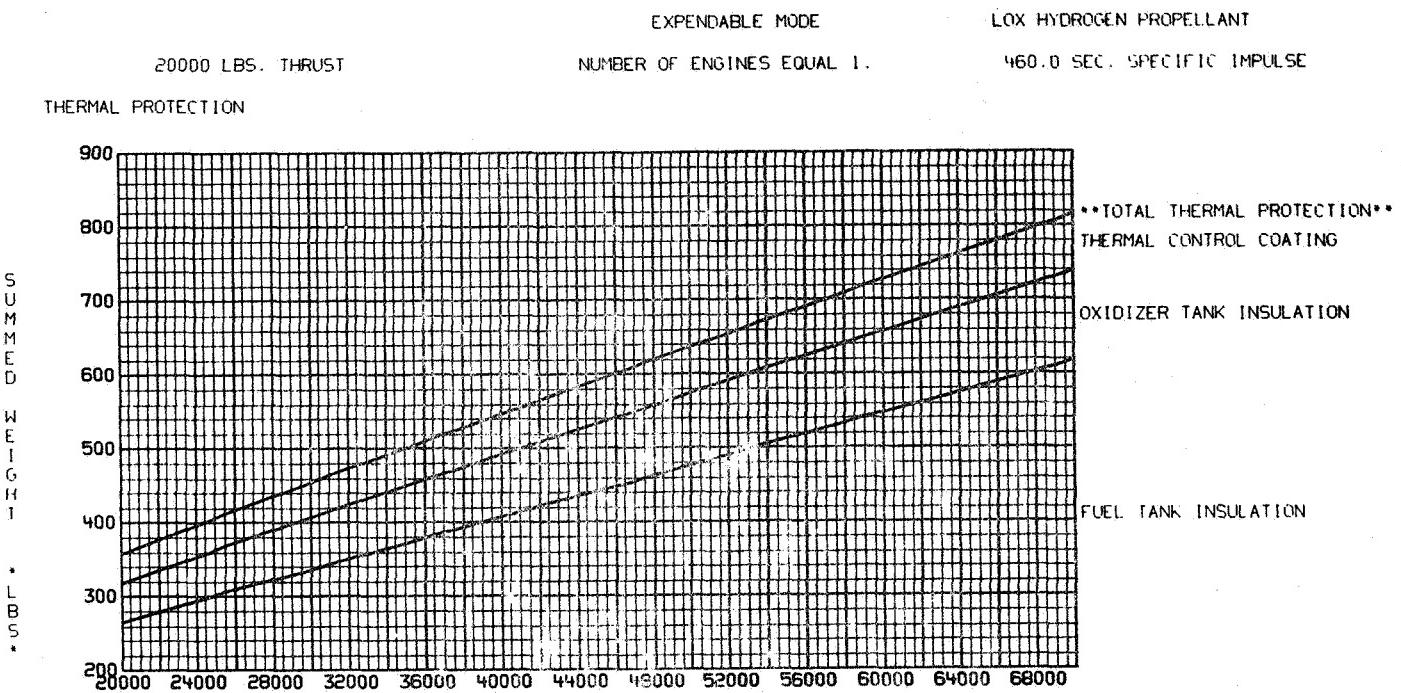


Figure 2-20

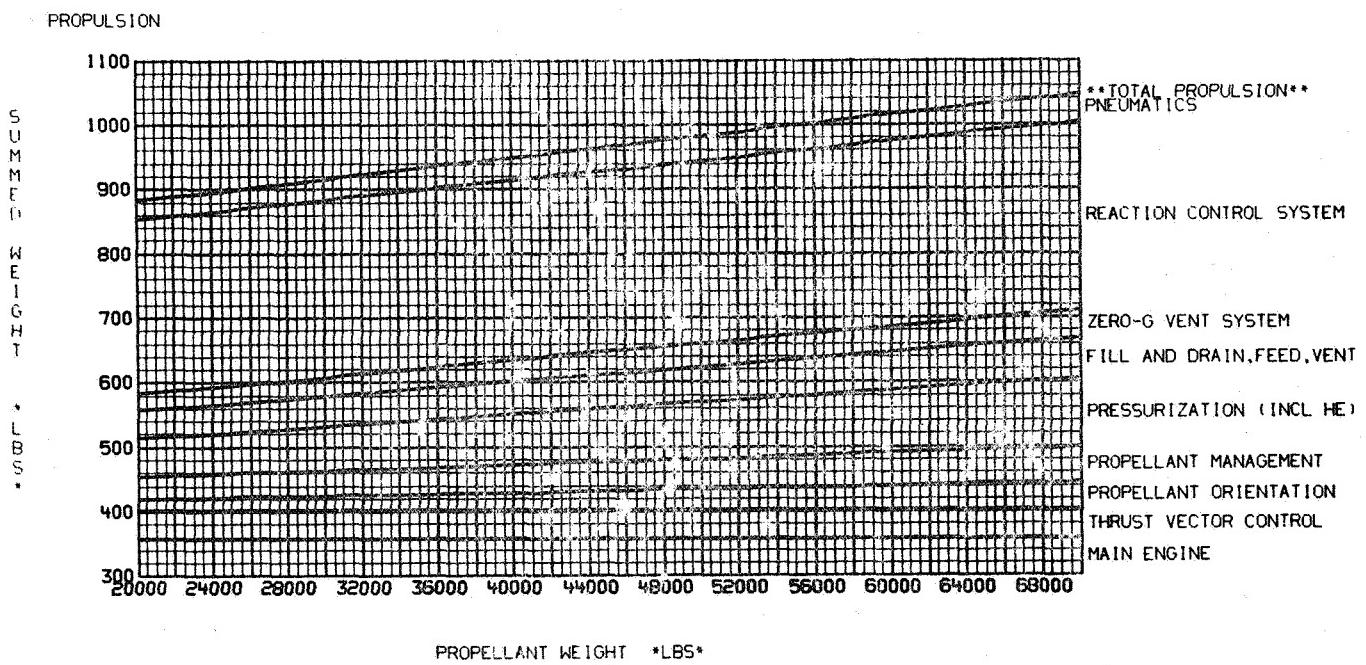


Figure 2-21

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

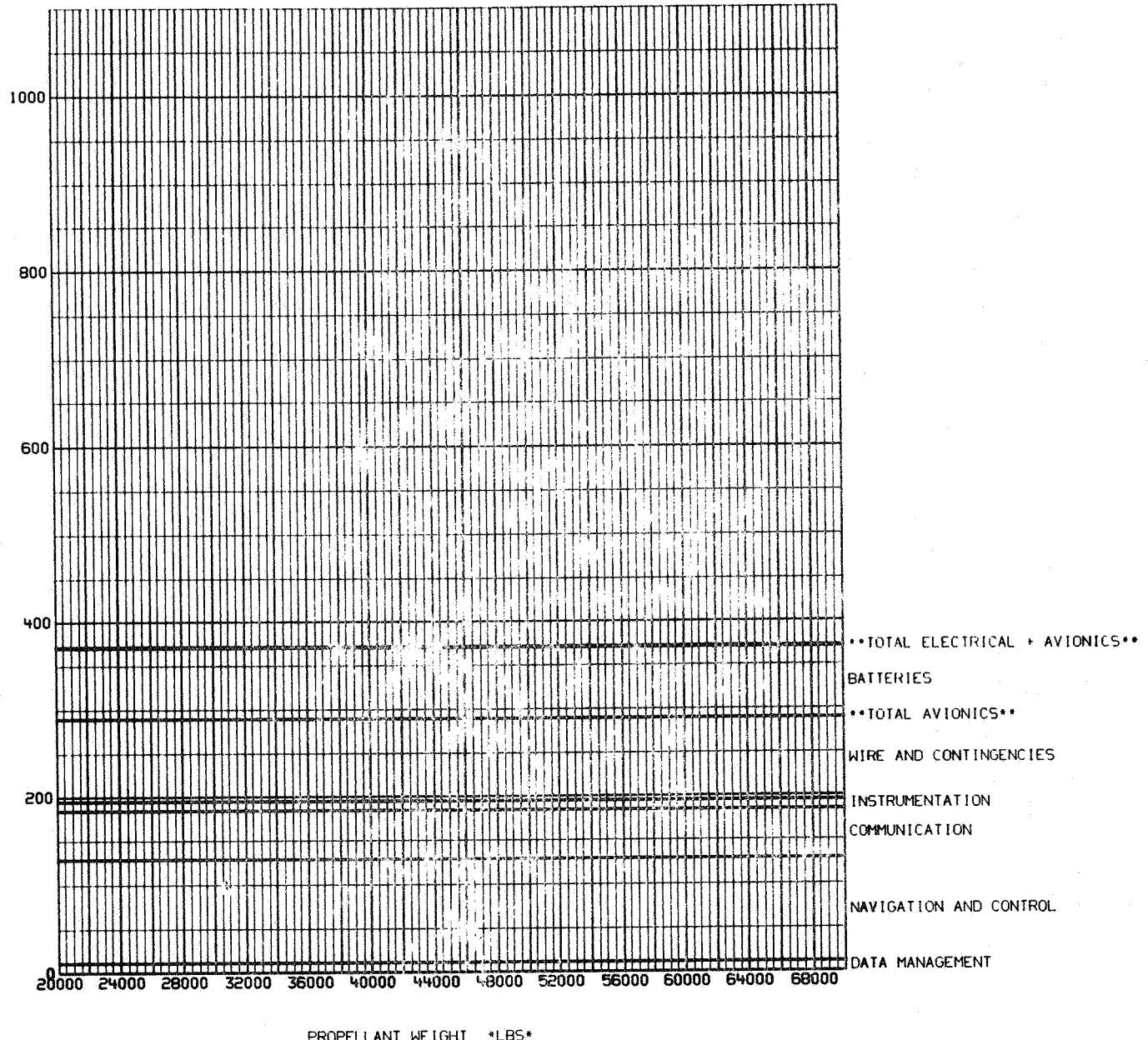


Figure 2-22

20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

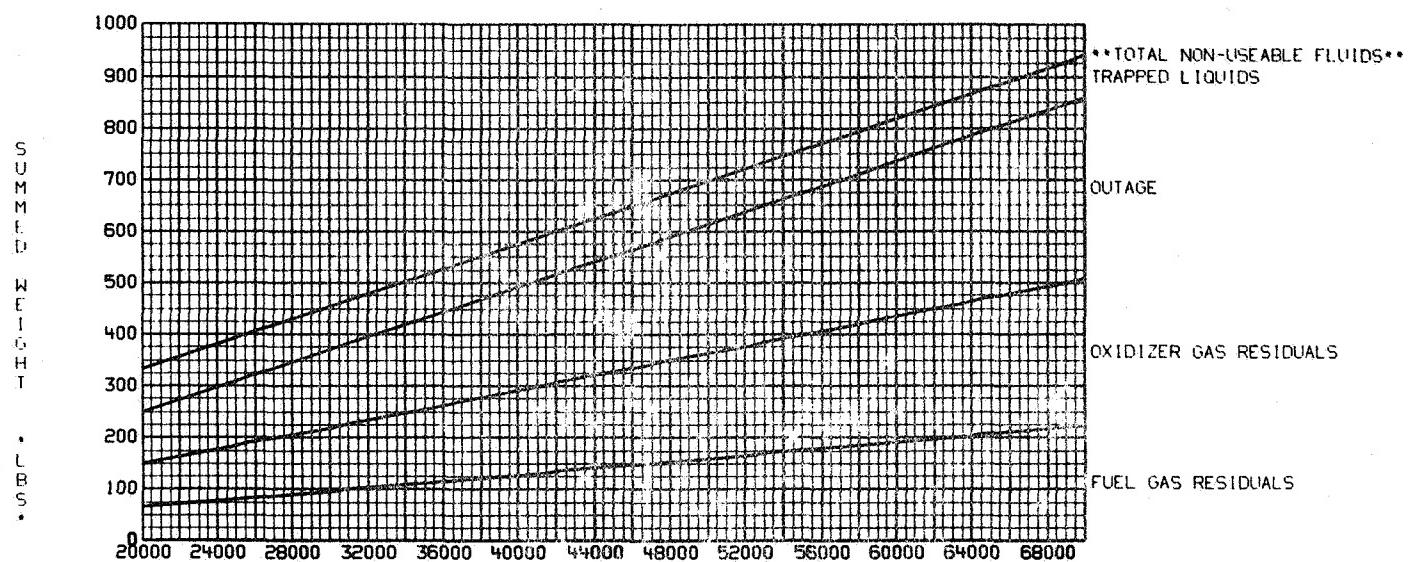


Figure 2-23

NON - IMPULSE CONSUMABLES

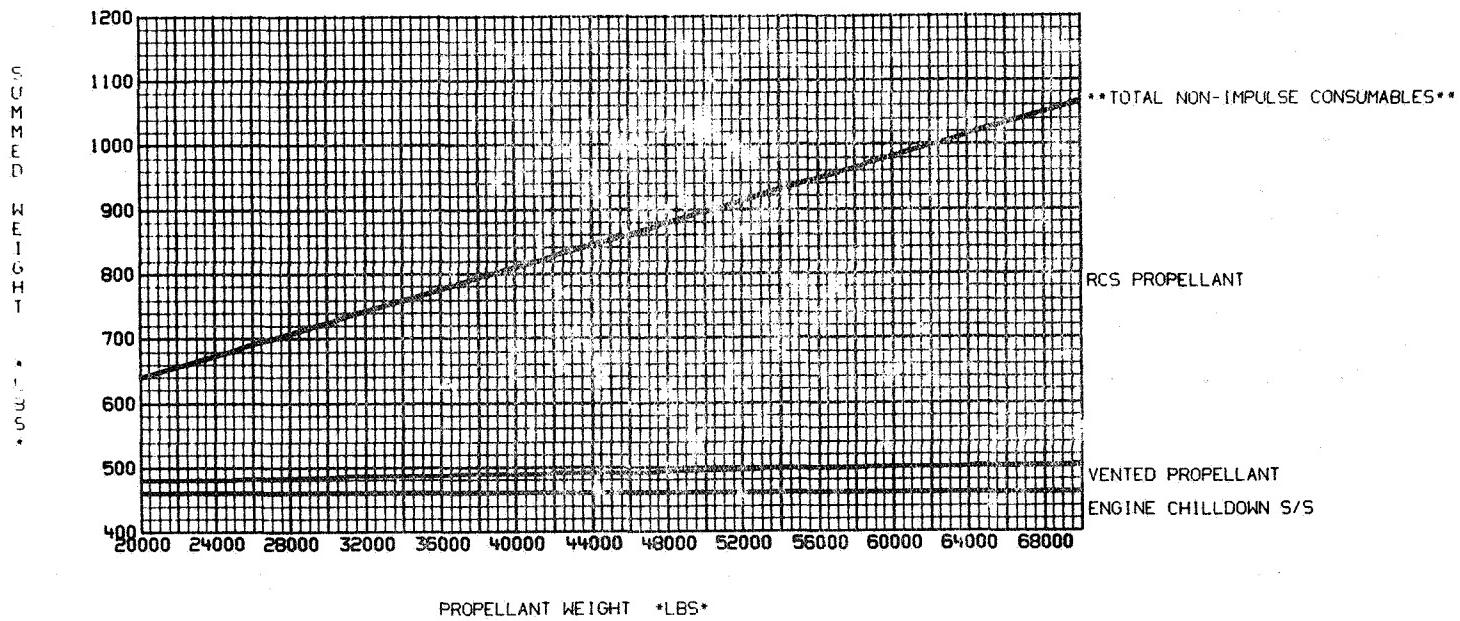


Figure 2-24

ADVANCED TPS SYSTEM WEIGHTS

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

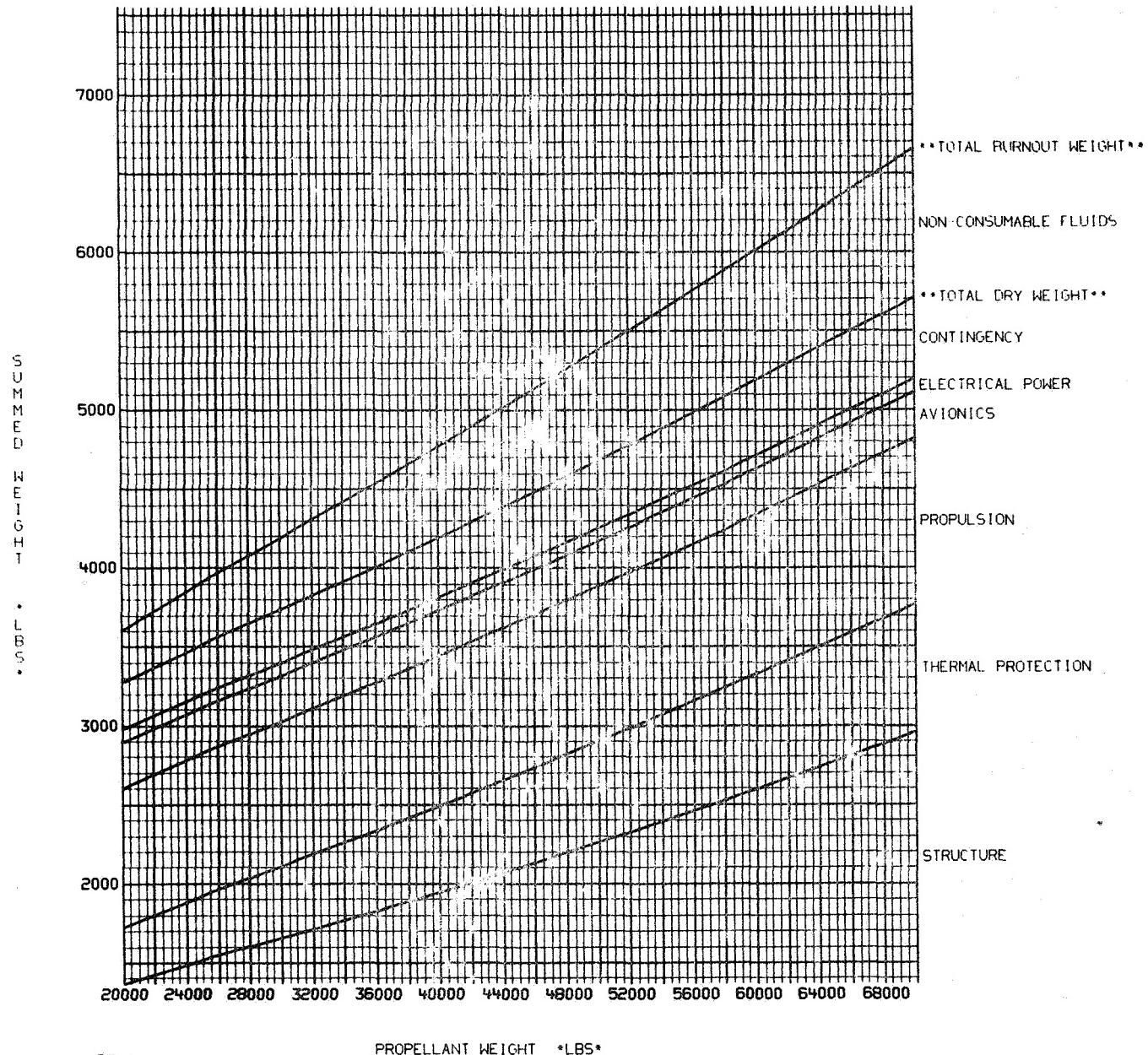


Figure 2-25

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

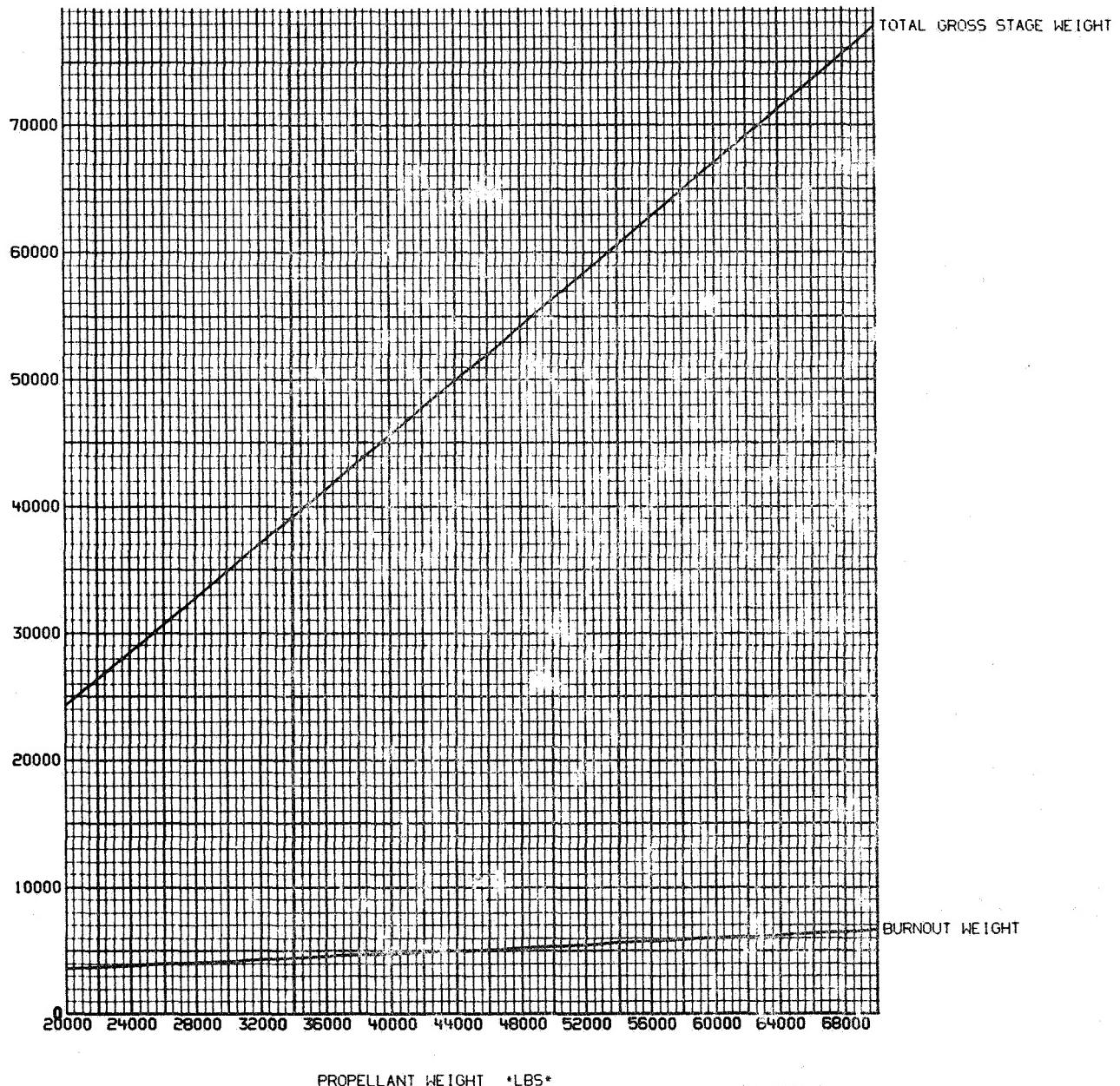


Figure 2-26

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

L
A
M
B
D
A
P
R
I
M
E

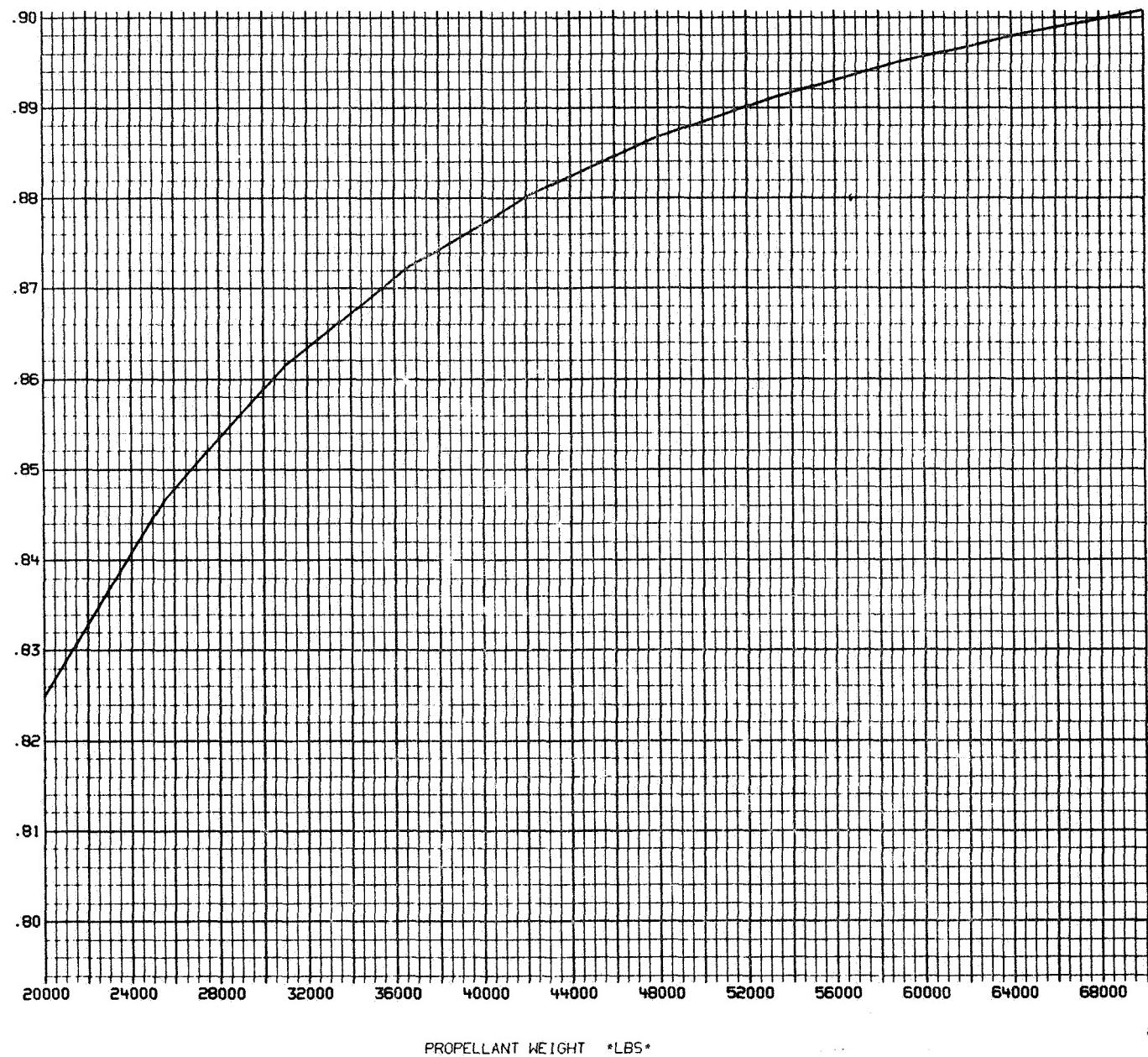


Figure 2-27

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

L
A
M
B
D
A
P
R
I
M
E

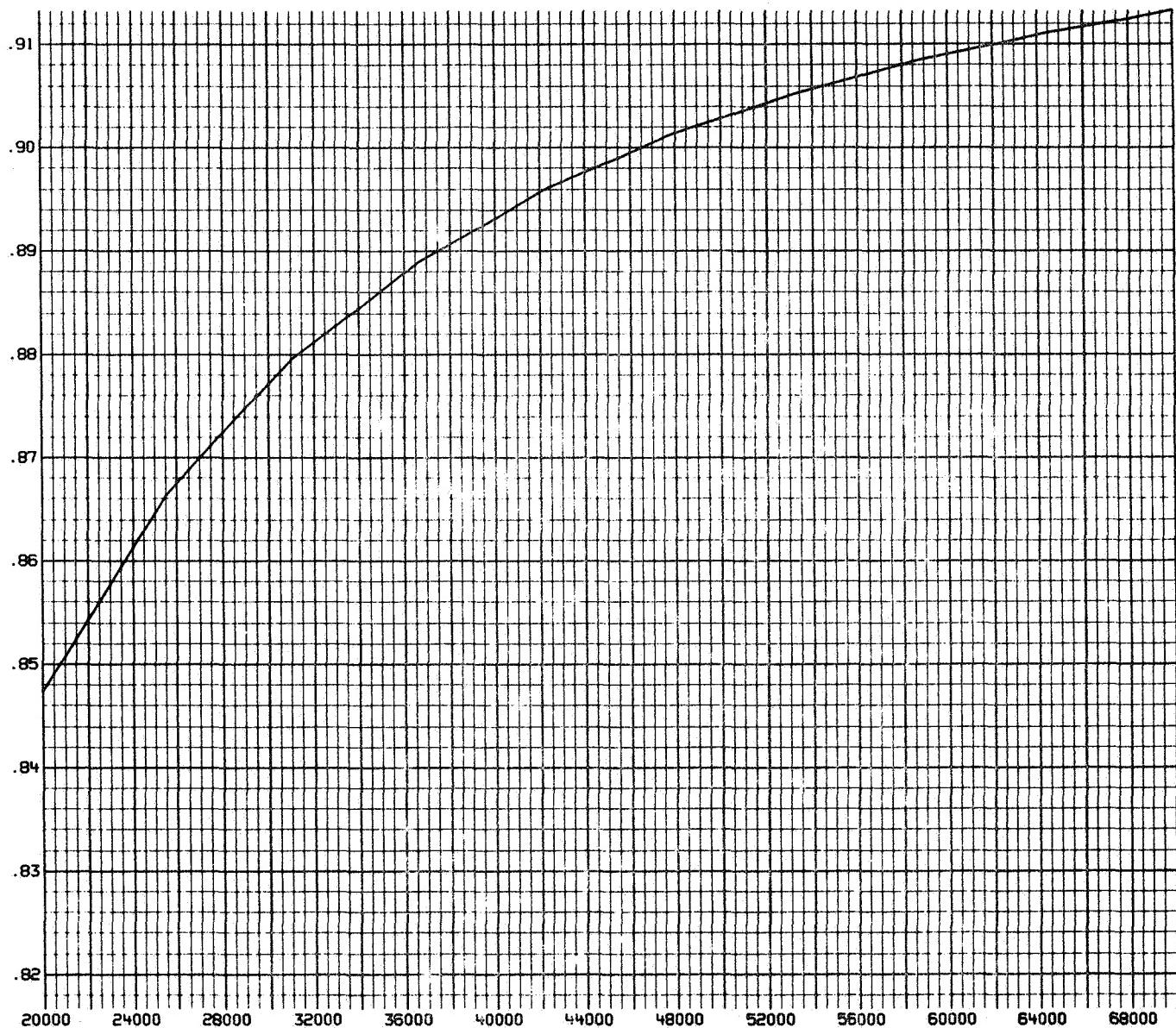


Figure 2-28

AREA OF CYLINDER + CONE

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

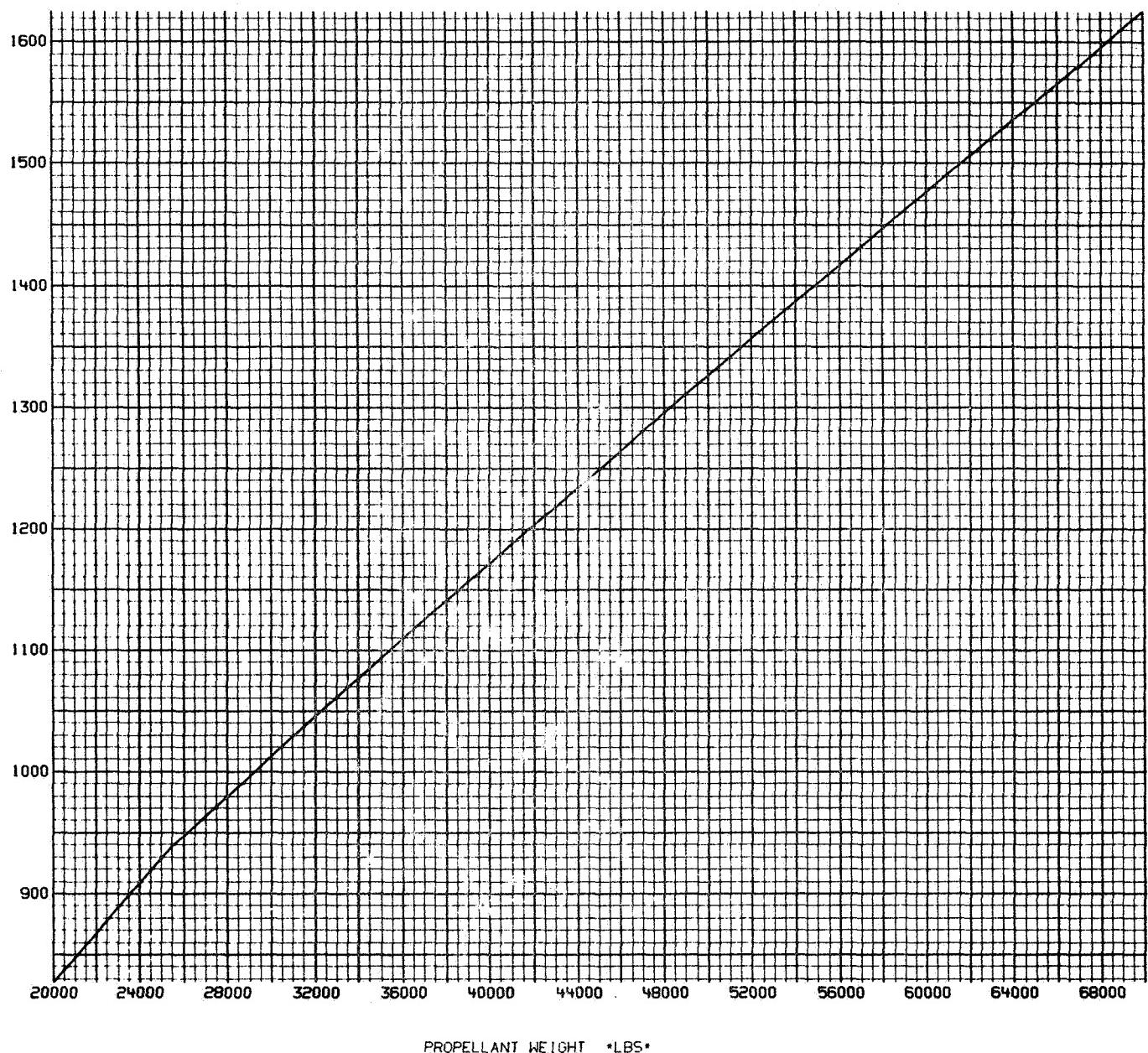


Figure 2-29

STRUHLA

20000 LBs. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

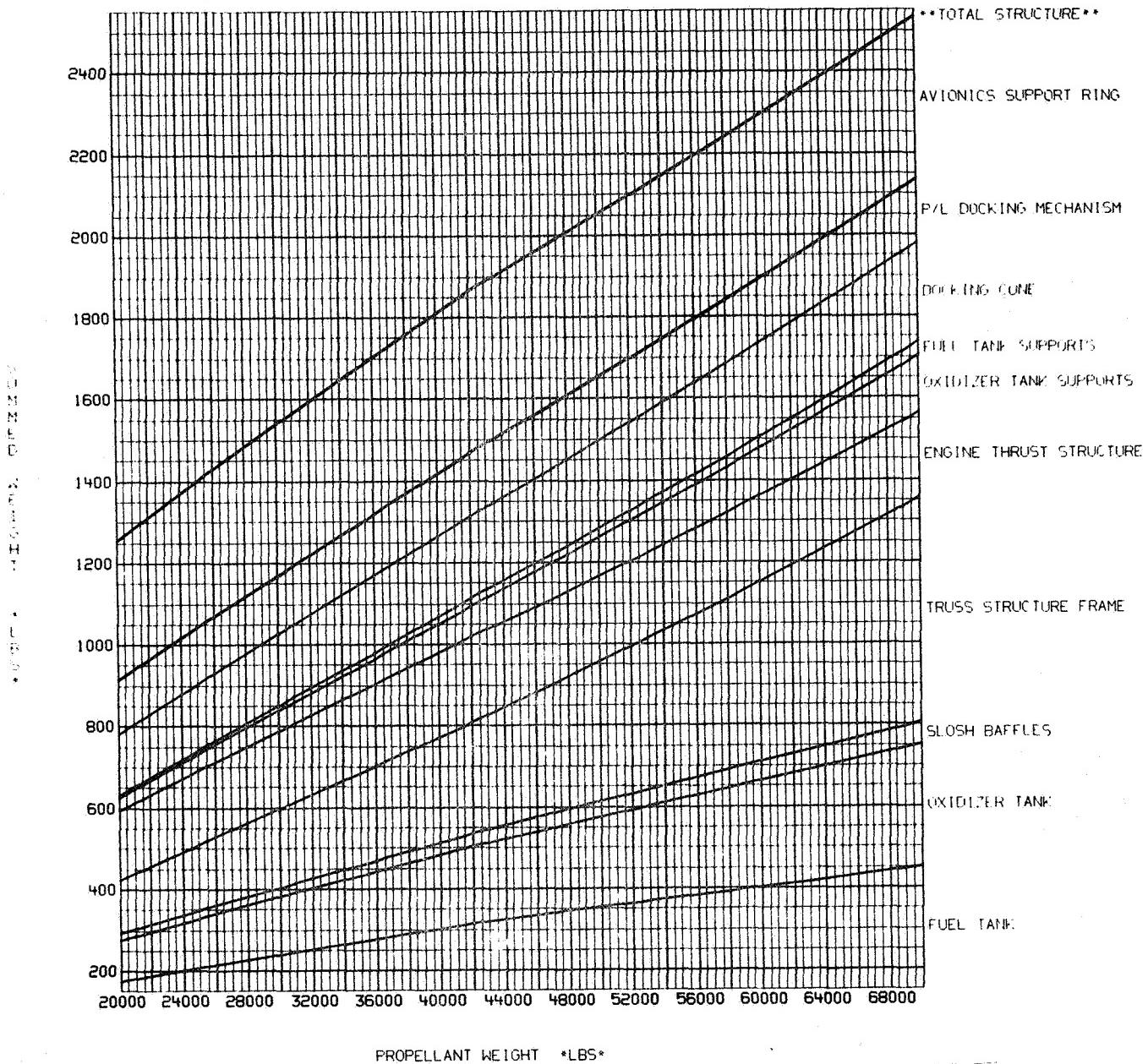


Figure 2-30

REUSABLE MODE	HYDROGEN FLUORINE PROPELLANT	
.20000 LBS. THRUST	NUMBER OF ENGINES EQUAL TO	474.4 SEC. SPECIFIC IMPULSE
THERMAL PROTECTION		

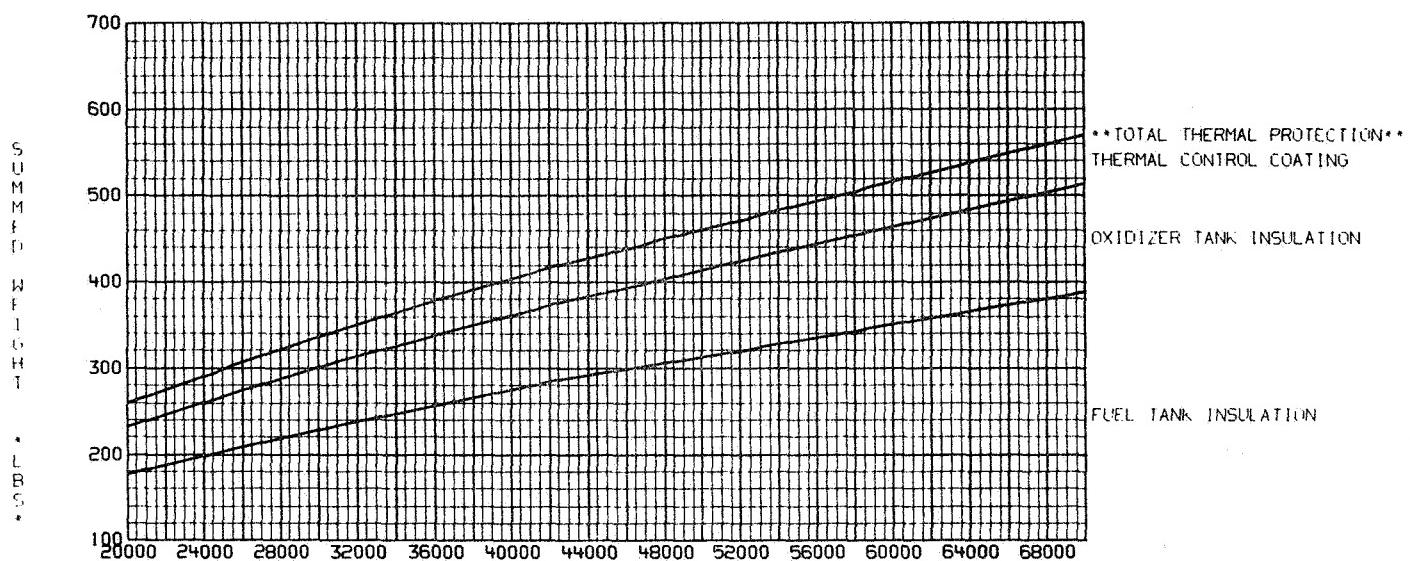


Figure 2-31

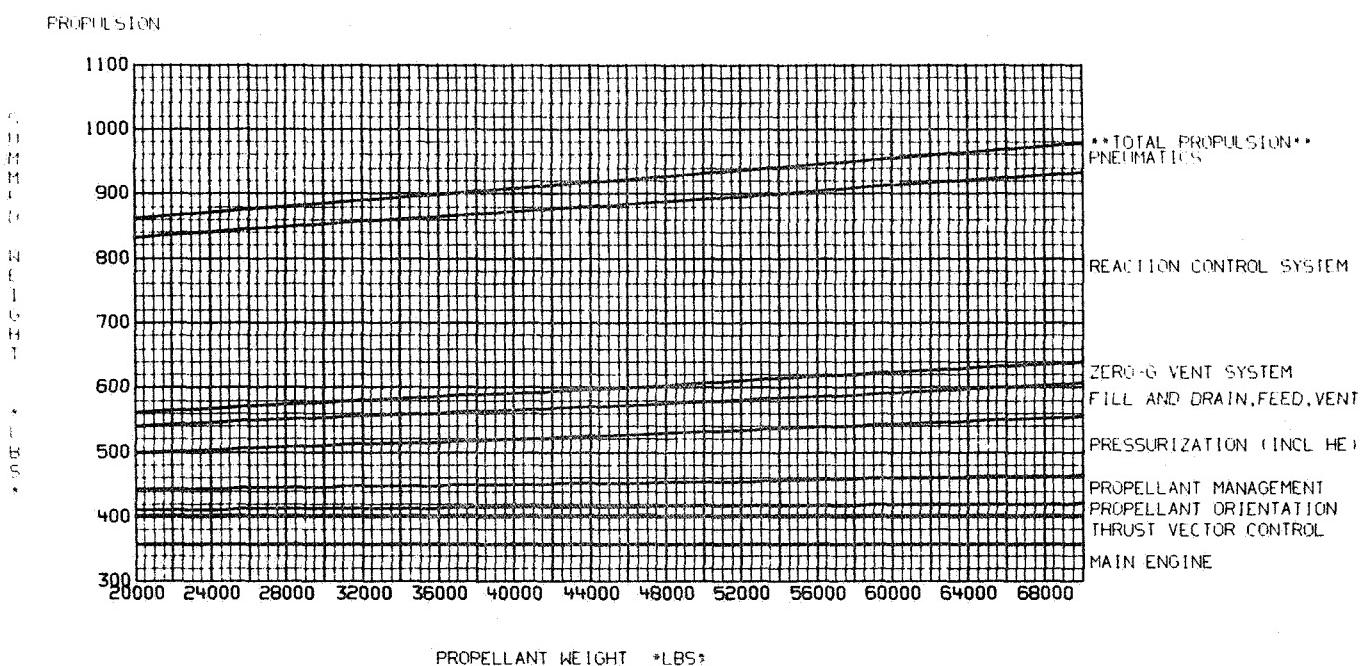


Figure 2-32

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

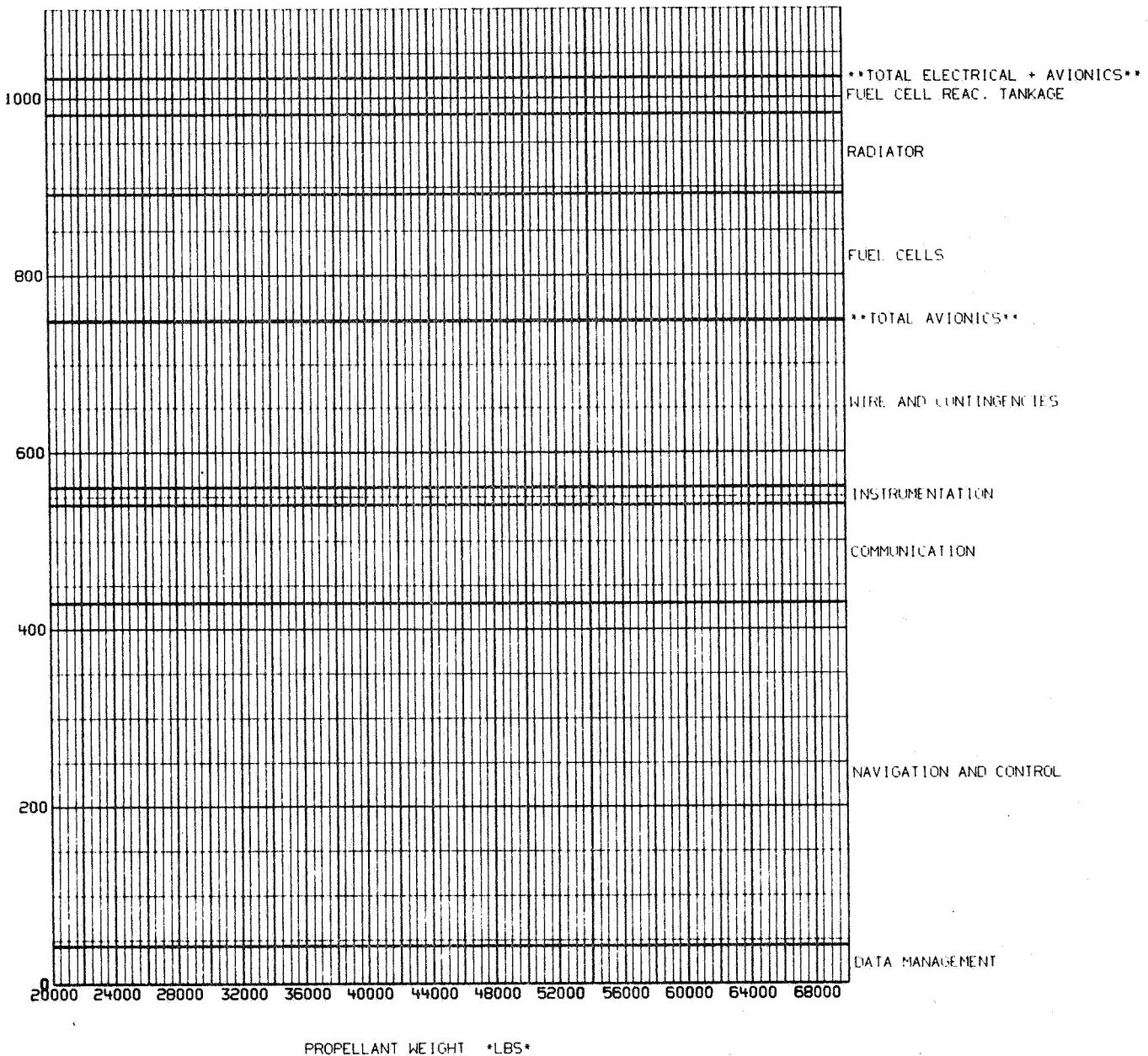


Figure 2-33

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.
20000 LBS. THRUST
NON - USEABLE FLUIDS
HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

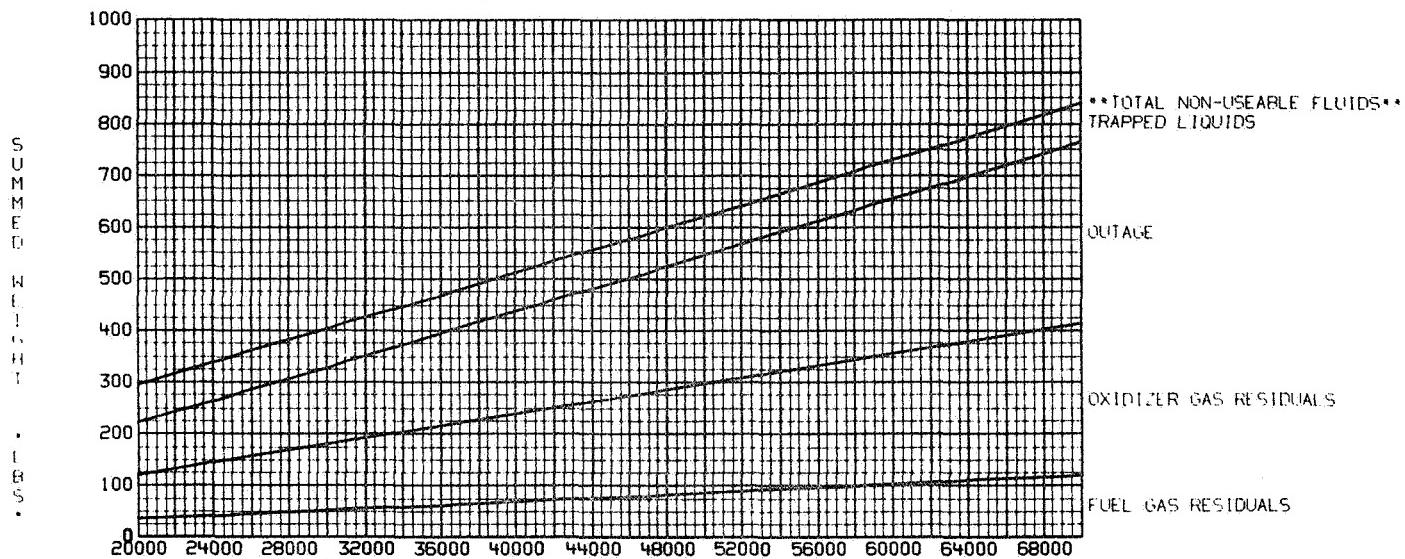


Figure 2-34

NON - IMPULSE CONSUMABLES

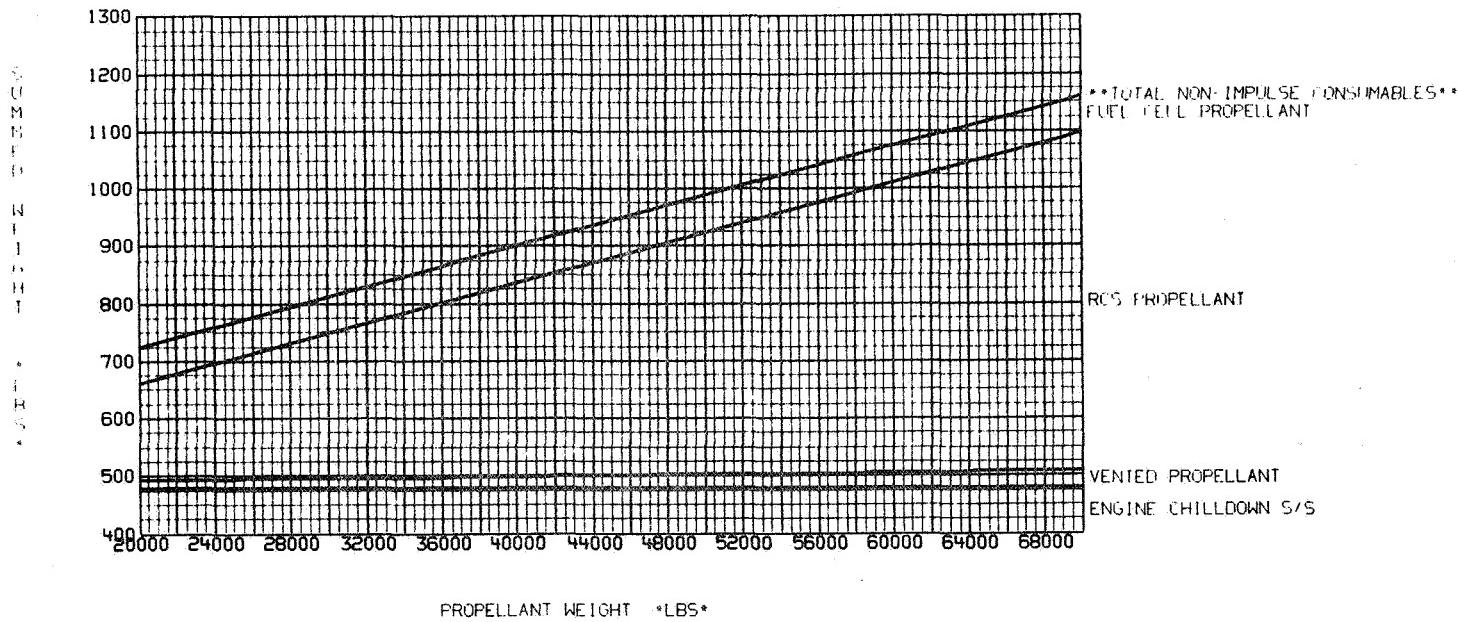


Figure 2-35

ADVANCED TPS SYSTEM WEIGHTS

70000 LBS. THRUST

REUSABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

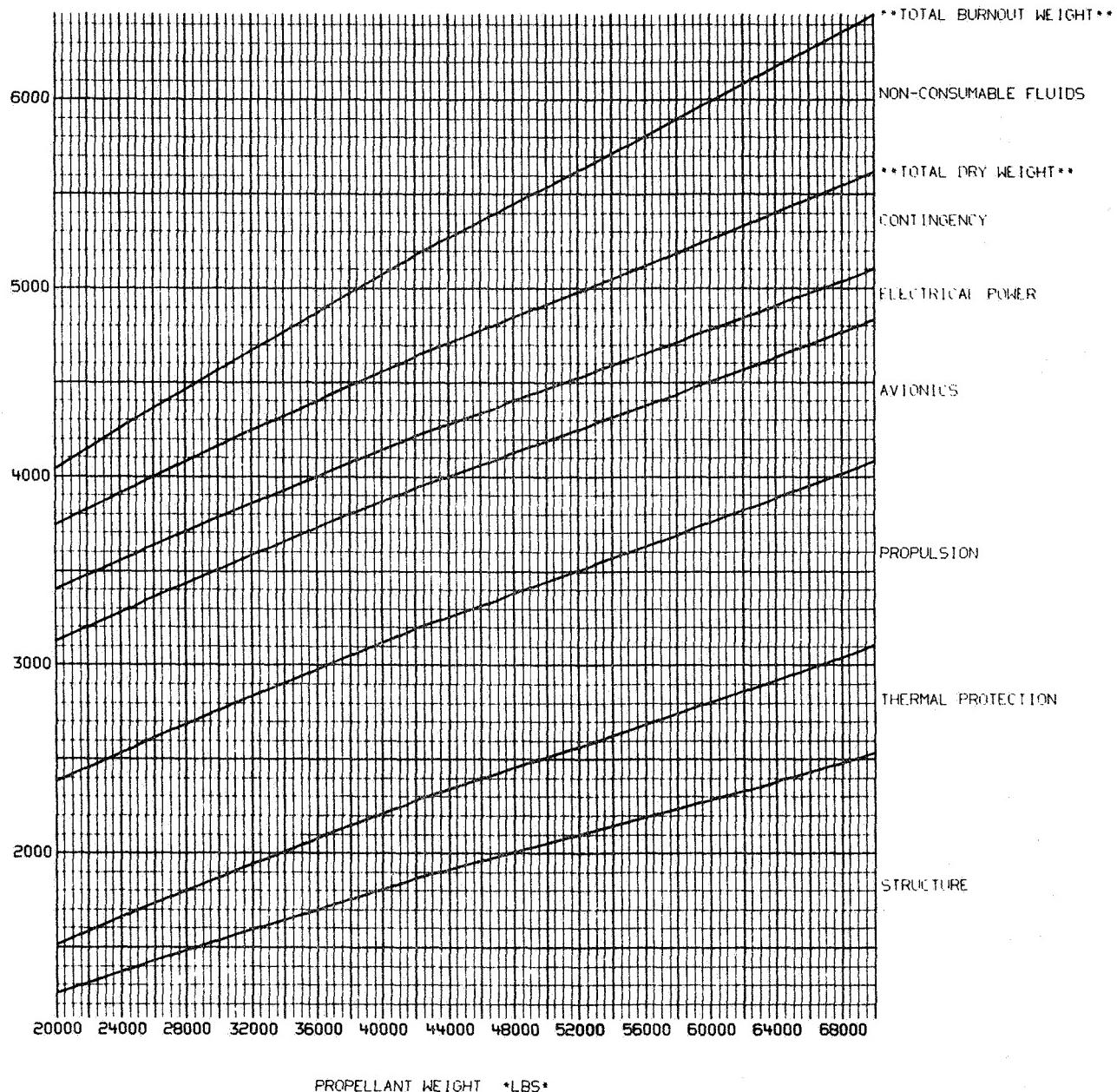


Figure 2-36

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

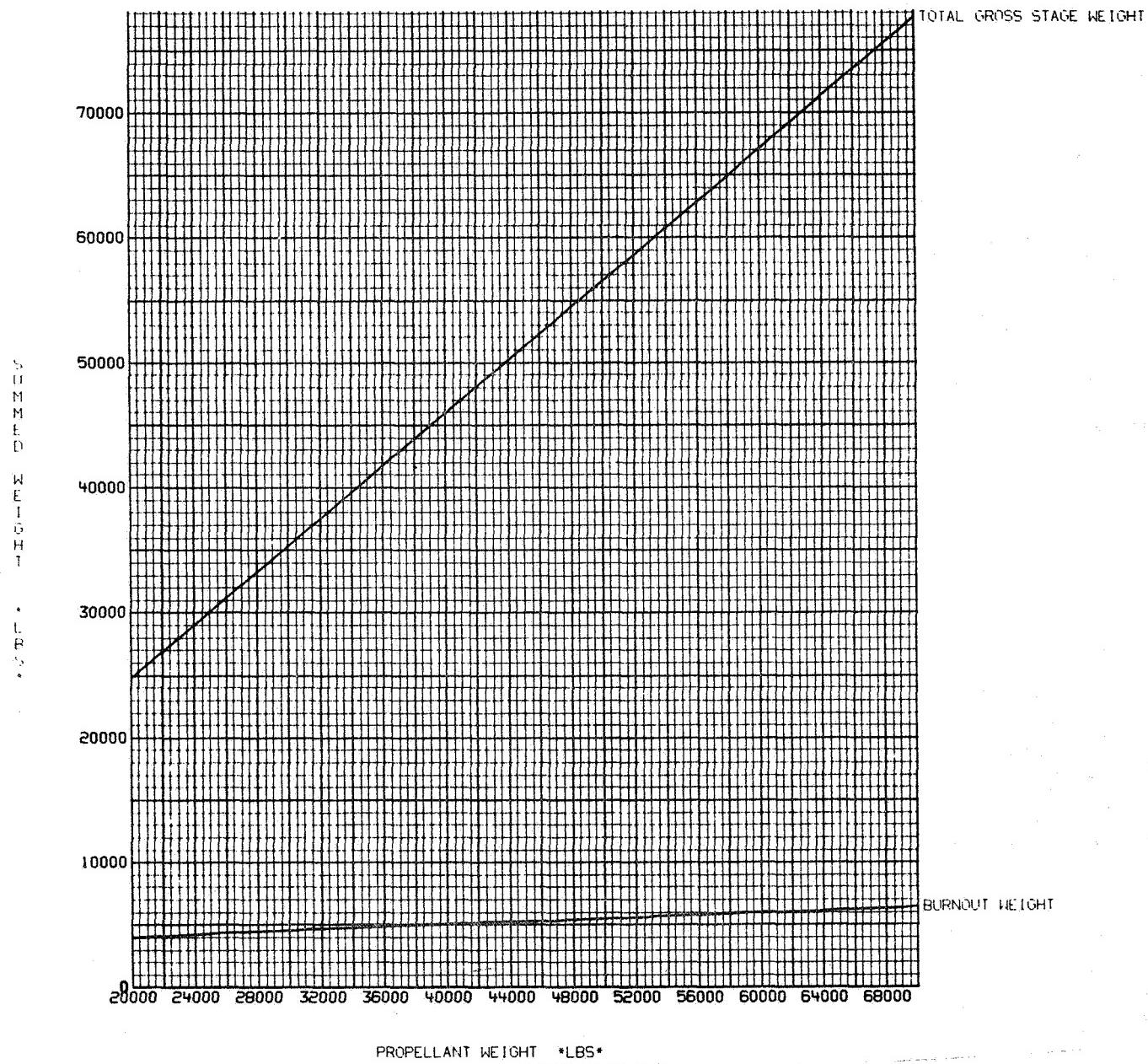


Figure 2-37

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
TURBINE ERG. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. REQUIRED IMPULSE

L
A
M
B
D
A
P
R
I
M
E

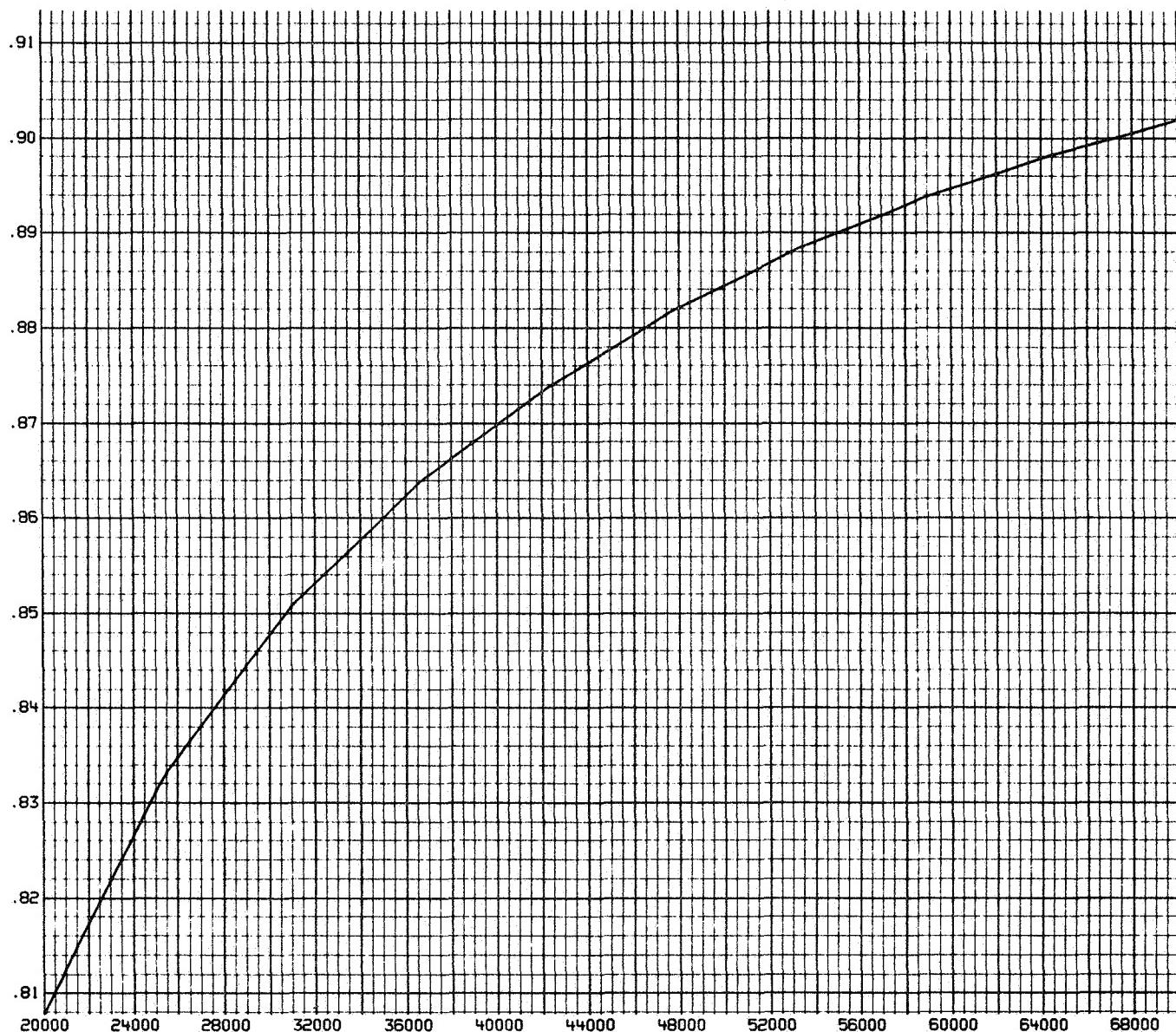


Figure 2-38

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

L
A
M
B
D
A
P
R
I
M
E

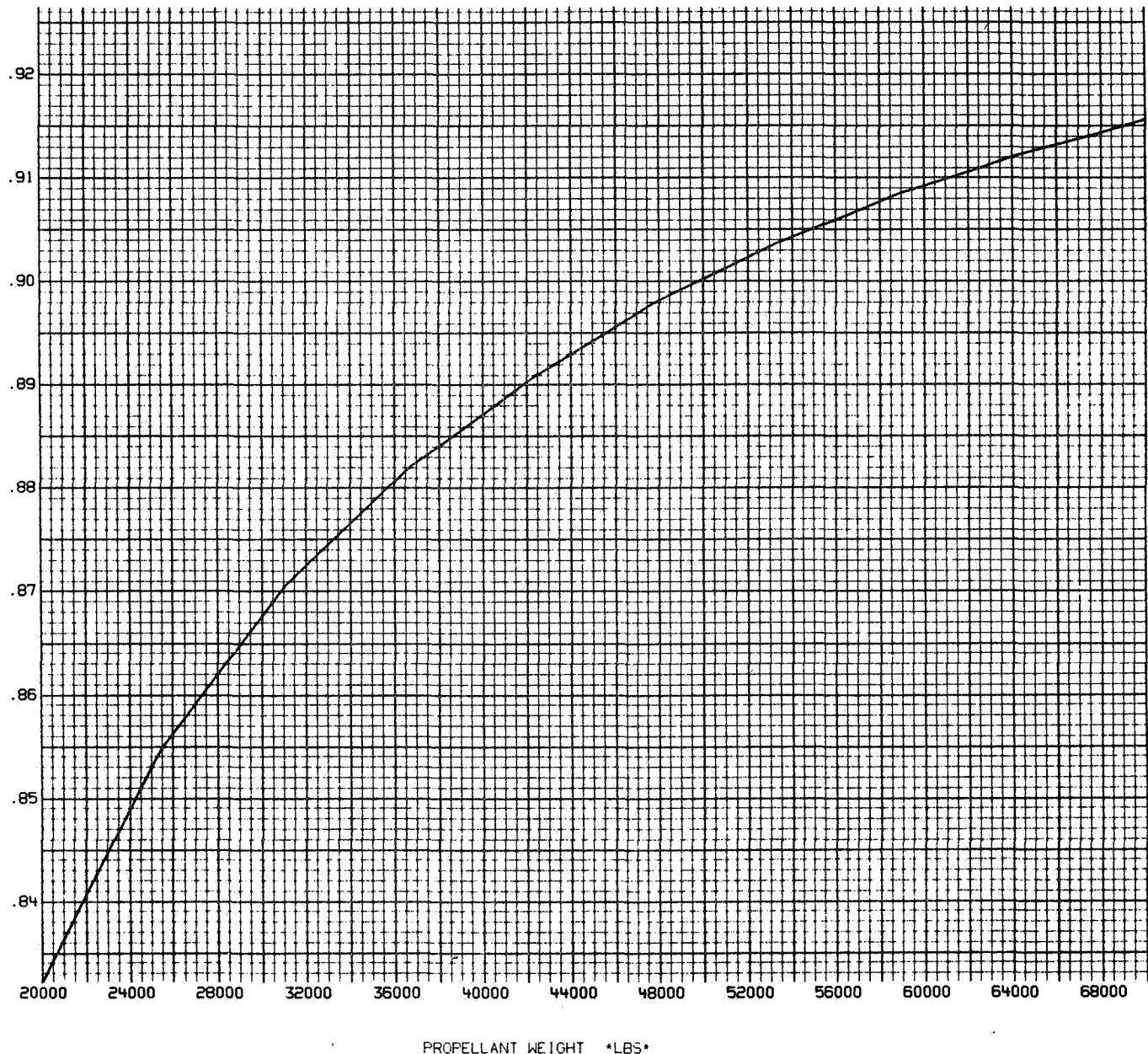


Figure 2-39

OXYDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

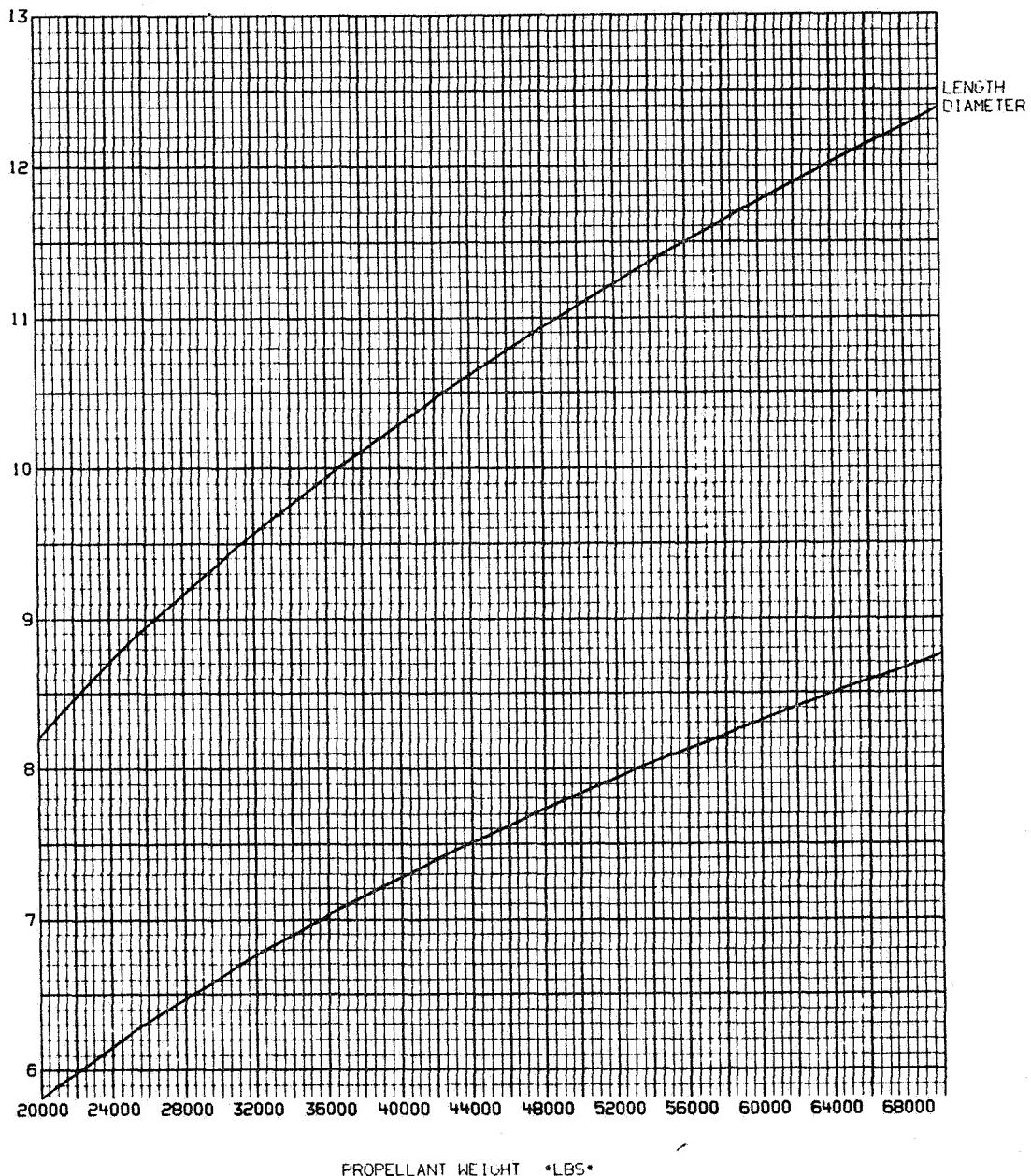


Figure 2-40

OXYGEN TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

974.4 SEC. SPECIFIC IMPULSE

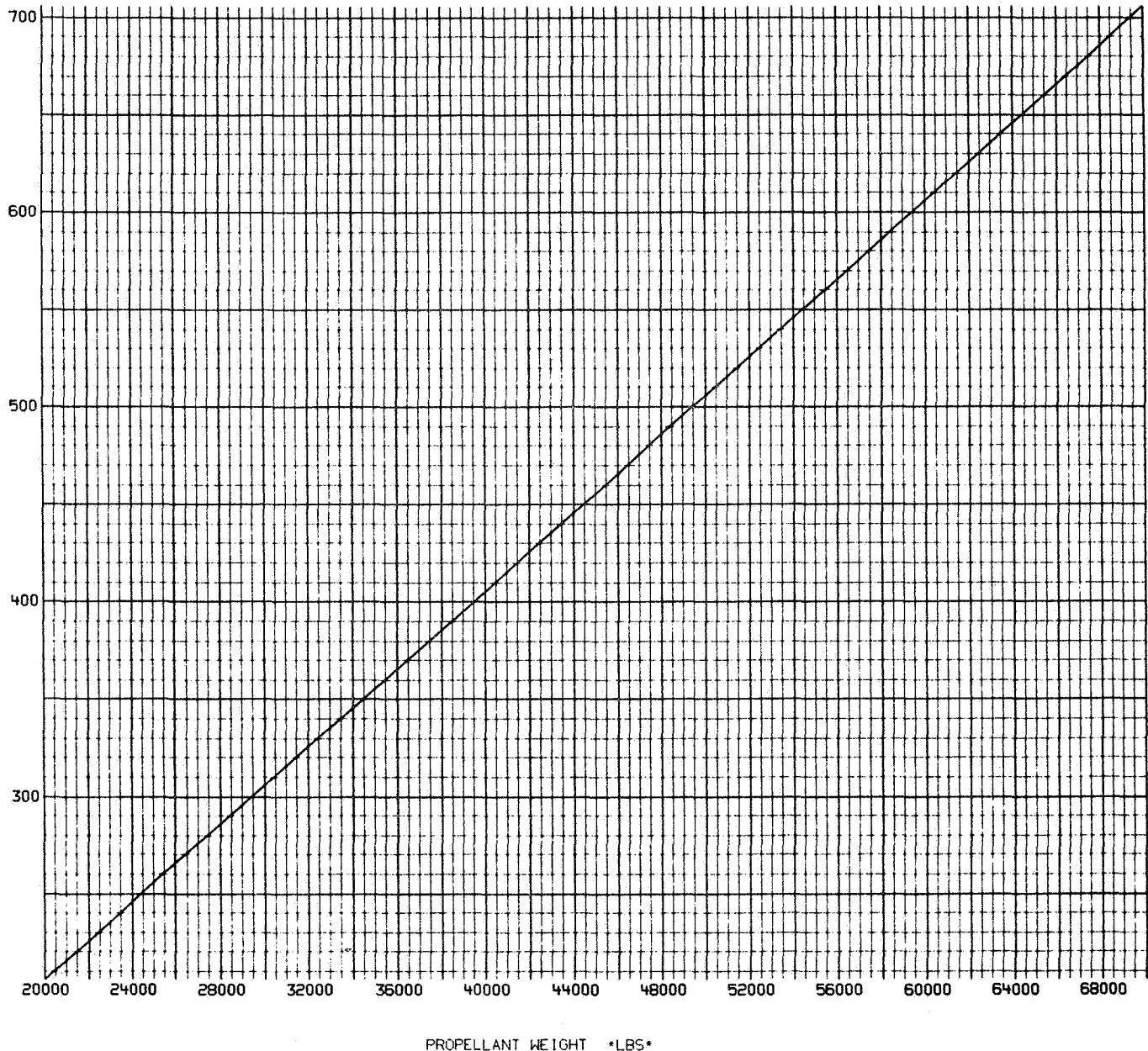


Figure 2-41

OXIDIZER TANK

60000 LBS. THRUST

HYDROGEN FLUORINE PROPELLANT

NUMBER OF ENGINES EQUAL 1.

474.4 SEC. SPECIFIC IMPULSE

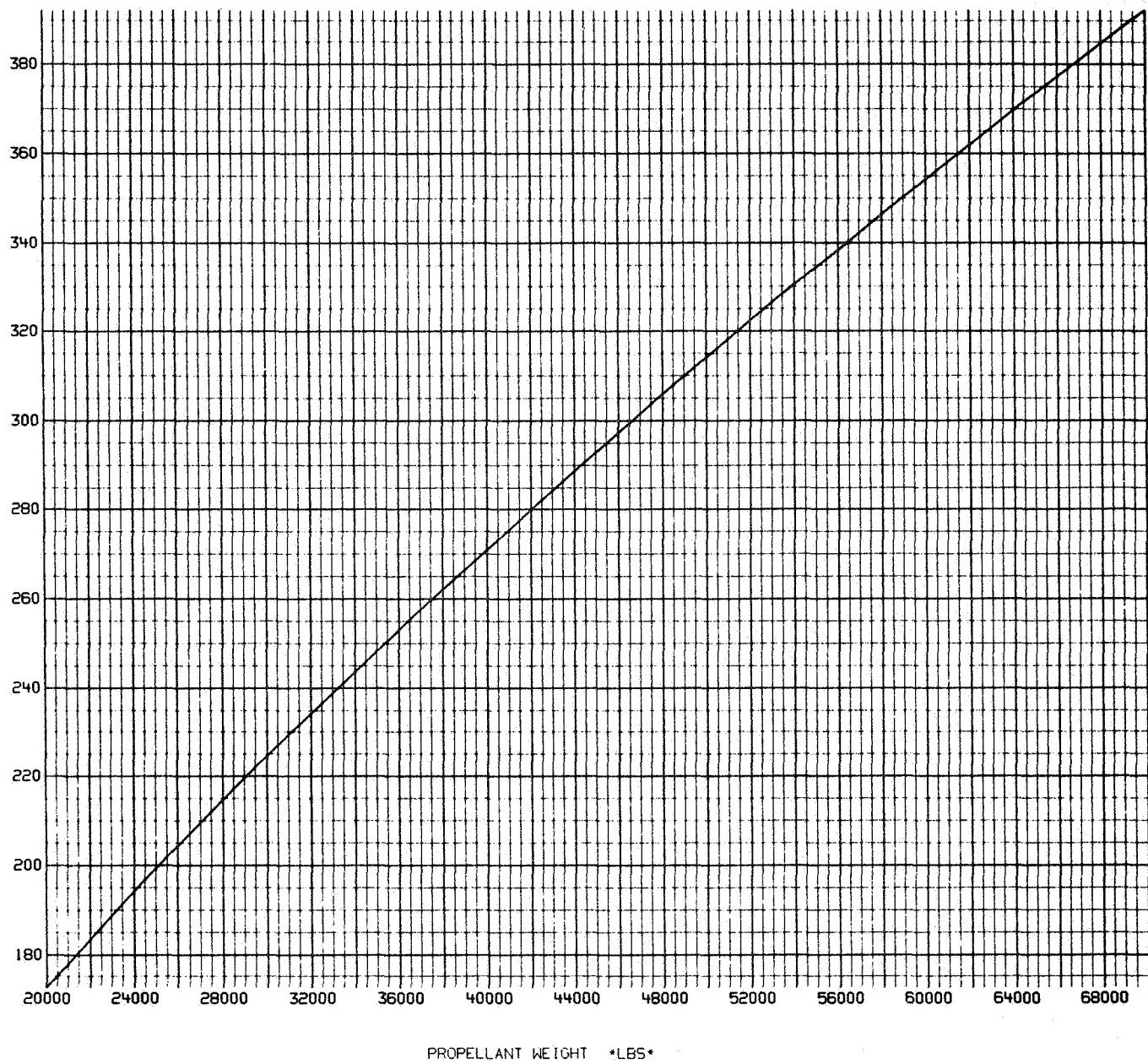


Figure 2-42

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

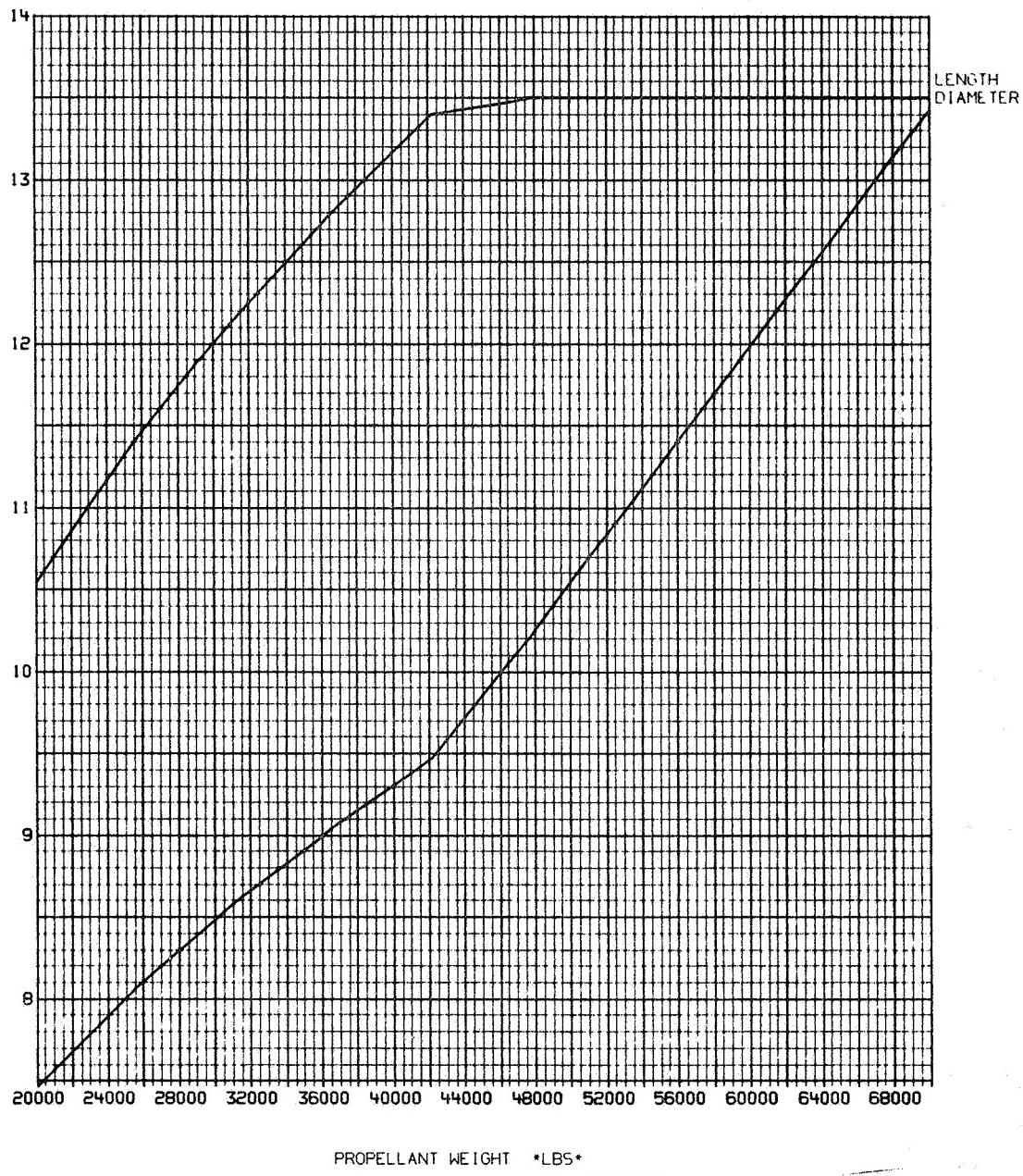


Figure 2-43

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

VOLUME FEET³

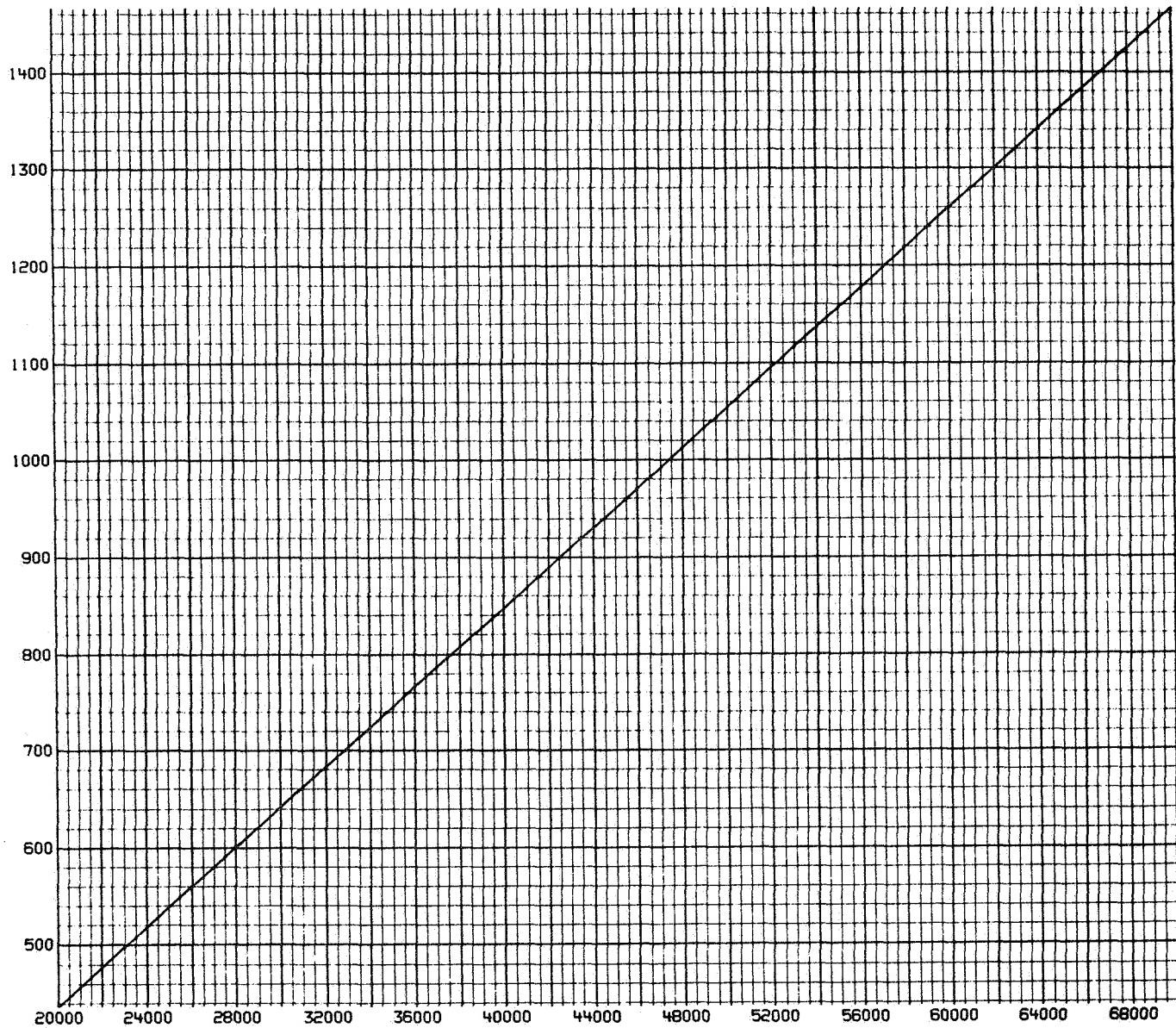


Figure 2-44

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

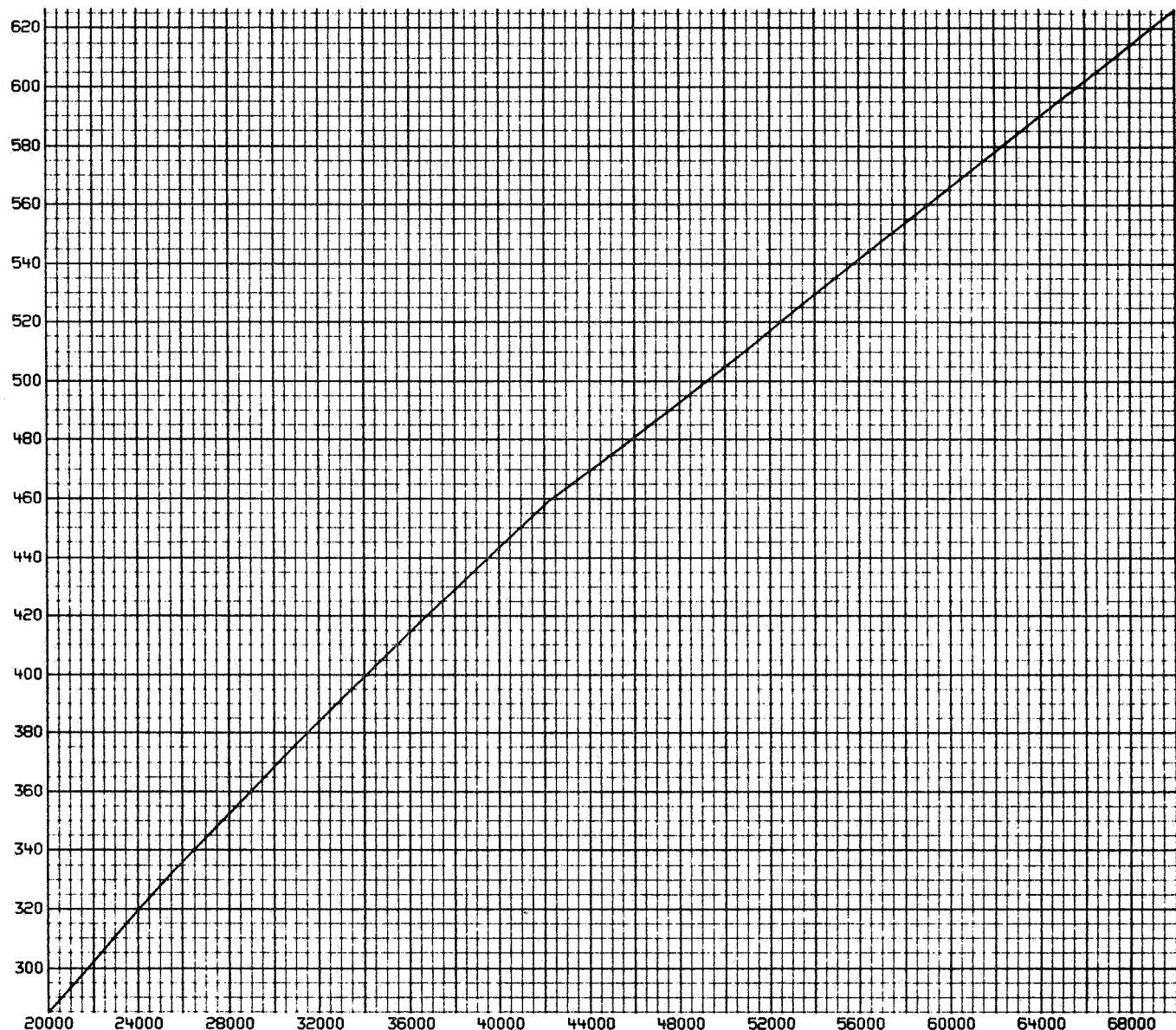
A
R
E
A
•
F
T
C

Figure 2-45

AREA OF CYLINDER = 1000

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

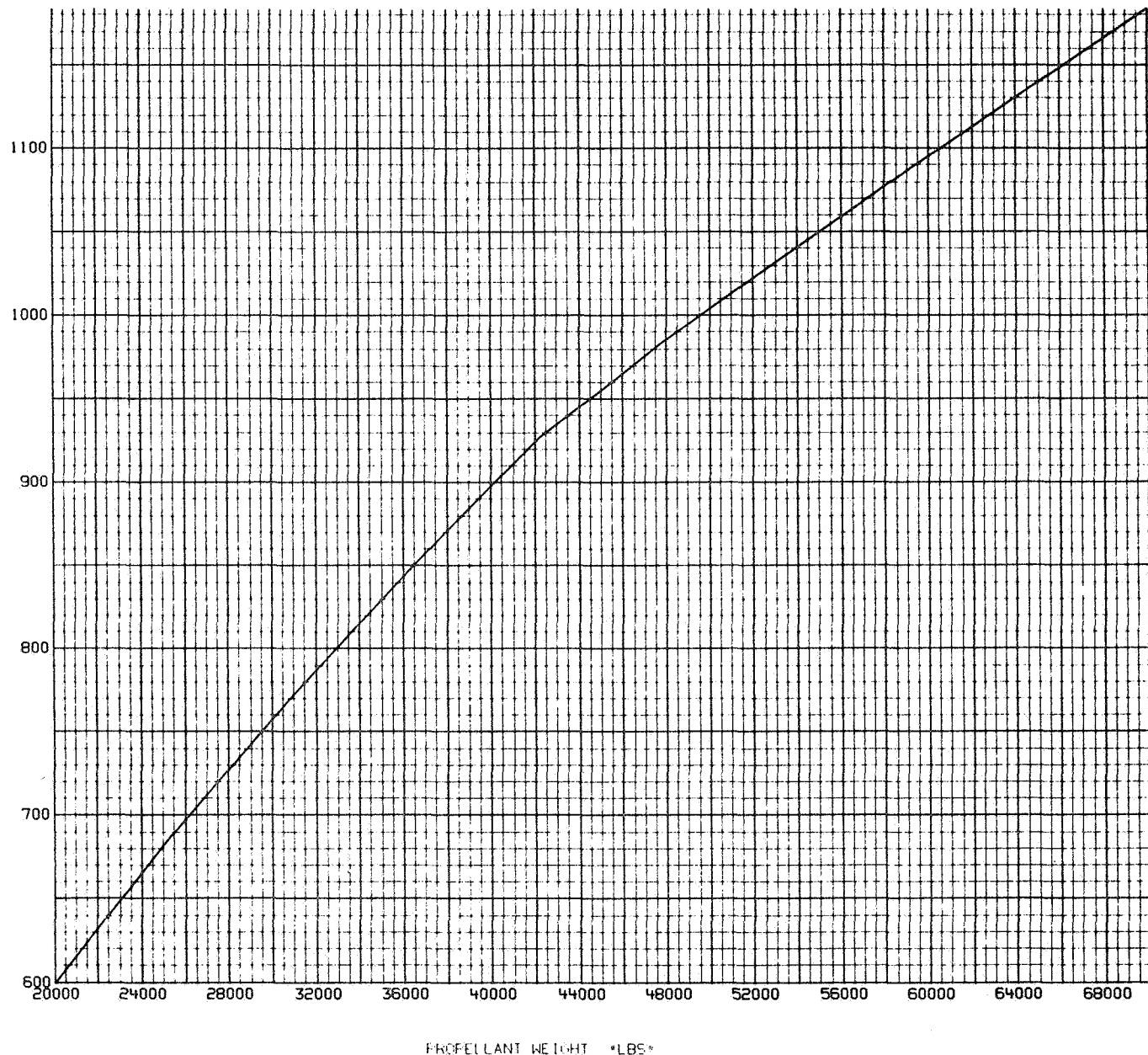


Figure 2-46

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

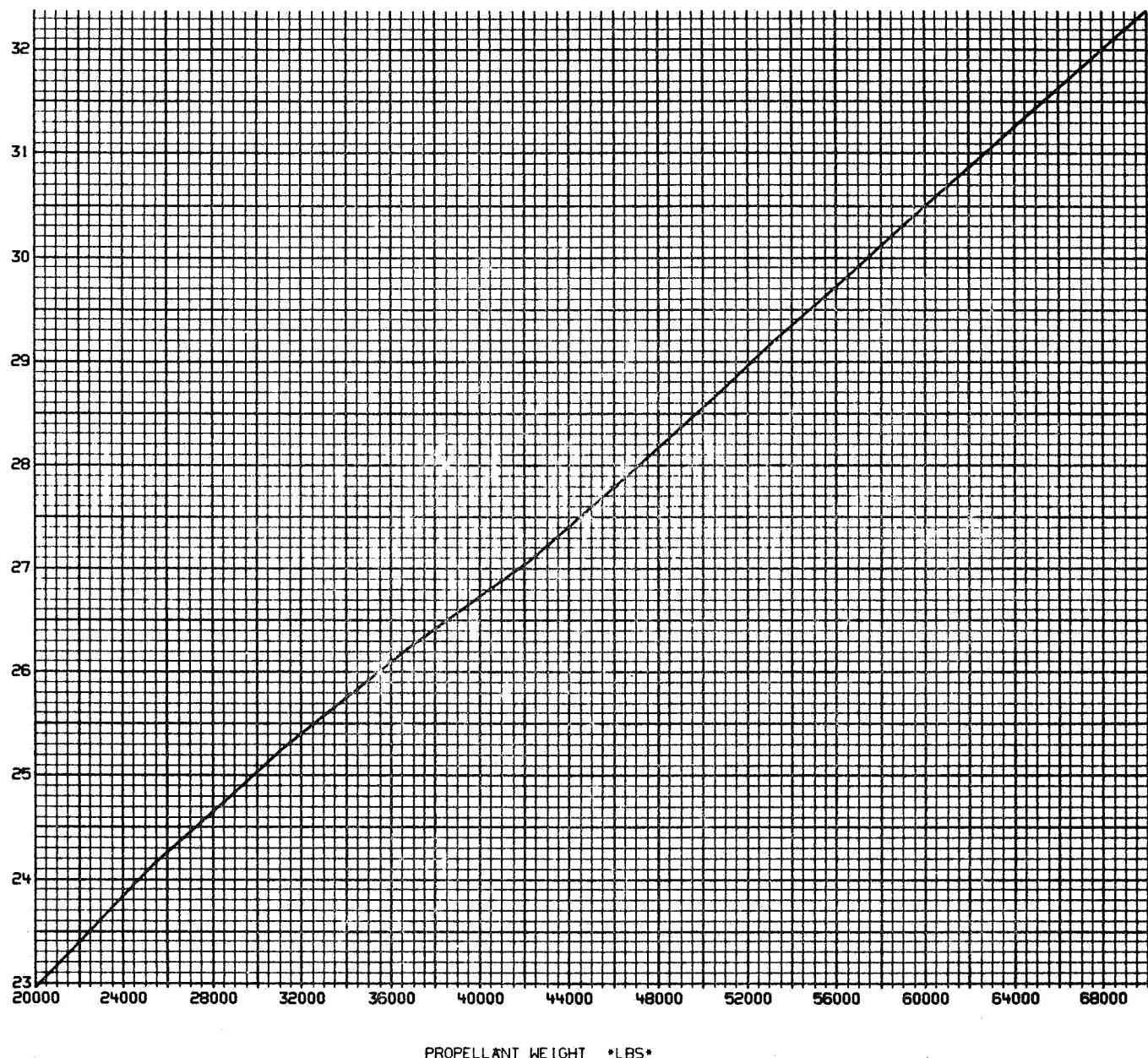


Figure 2-47

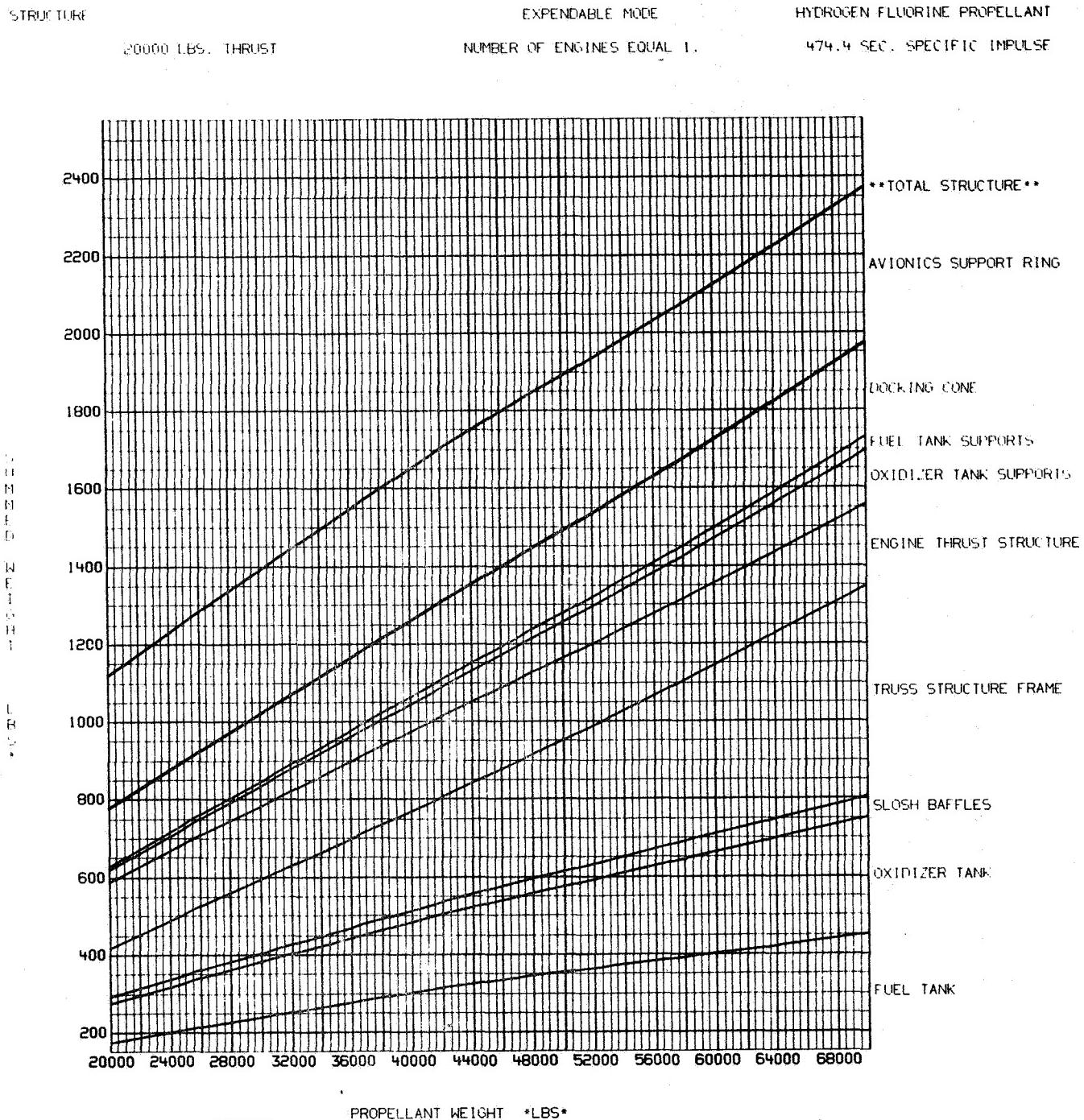


Figure 2-48

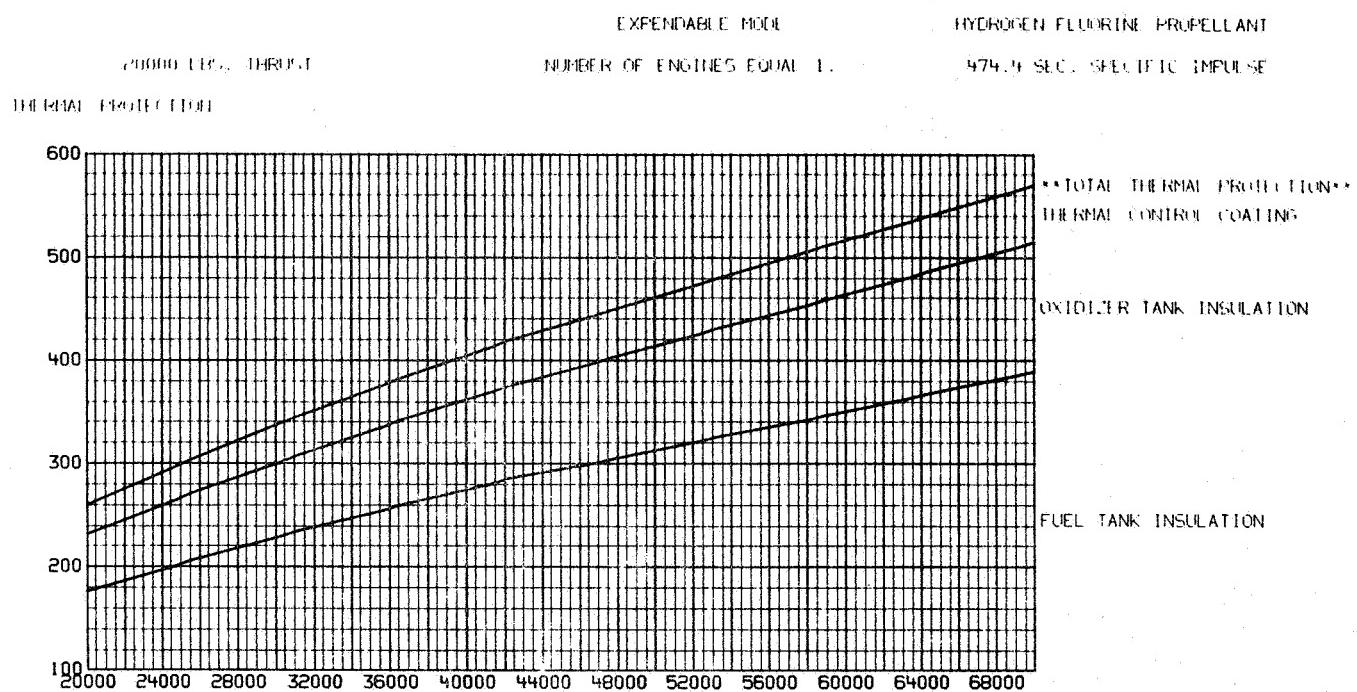


Figure 2-49

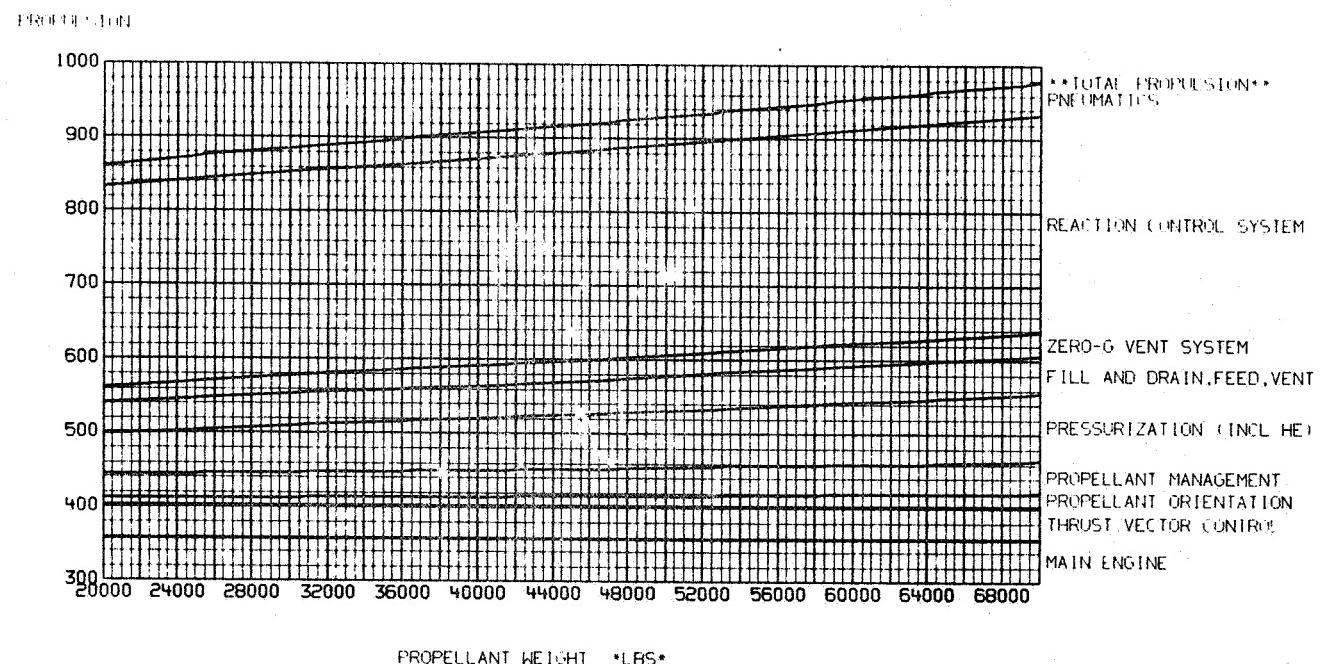


Figure 2-50

AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

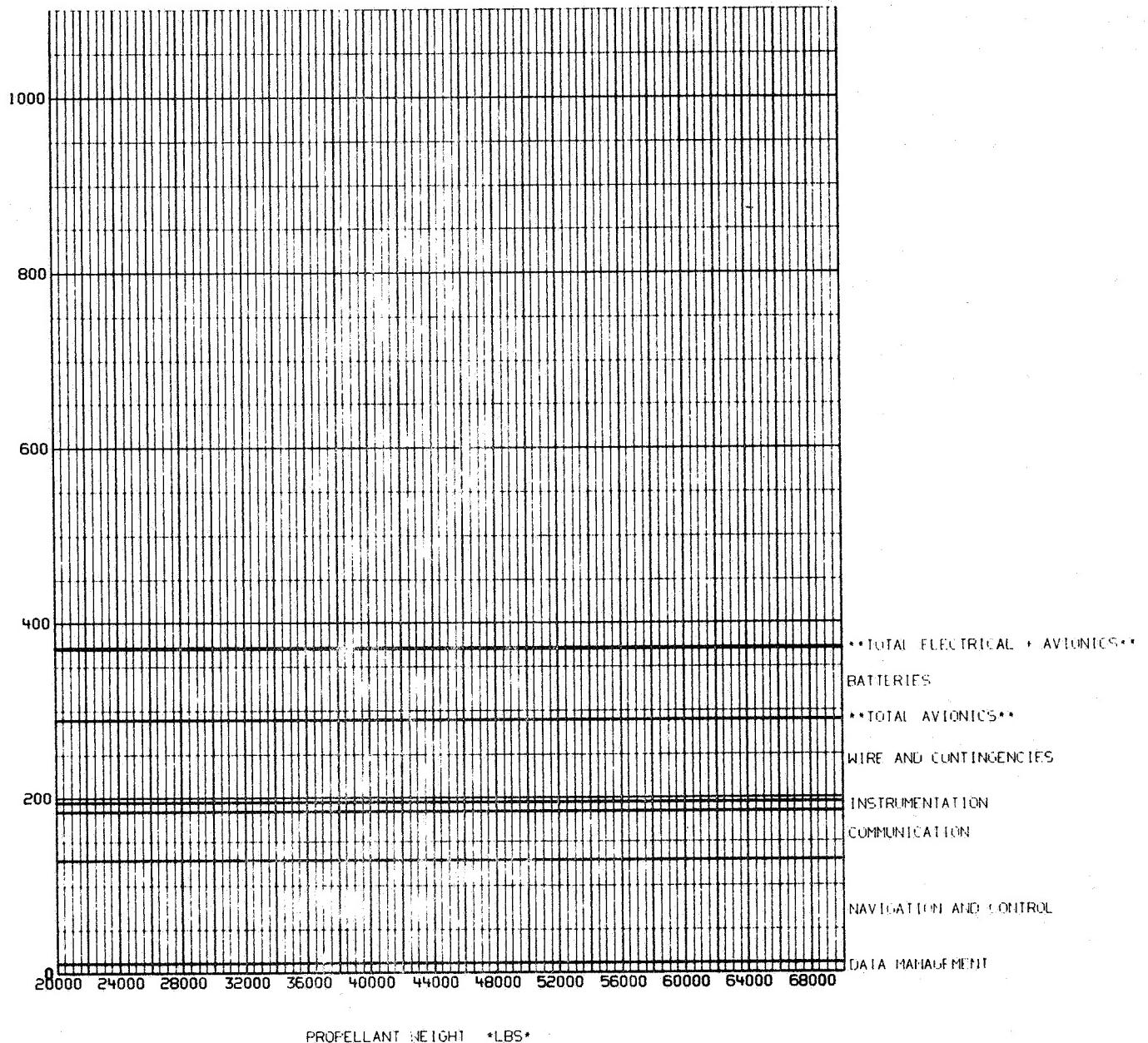


Figure 2-51

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.
474.4 SEC. SPECIFIC IMPULSE
20000 LBS. THRUST
NON USEABLE FLUIDS

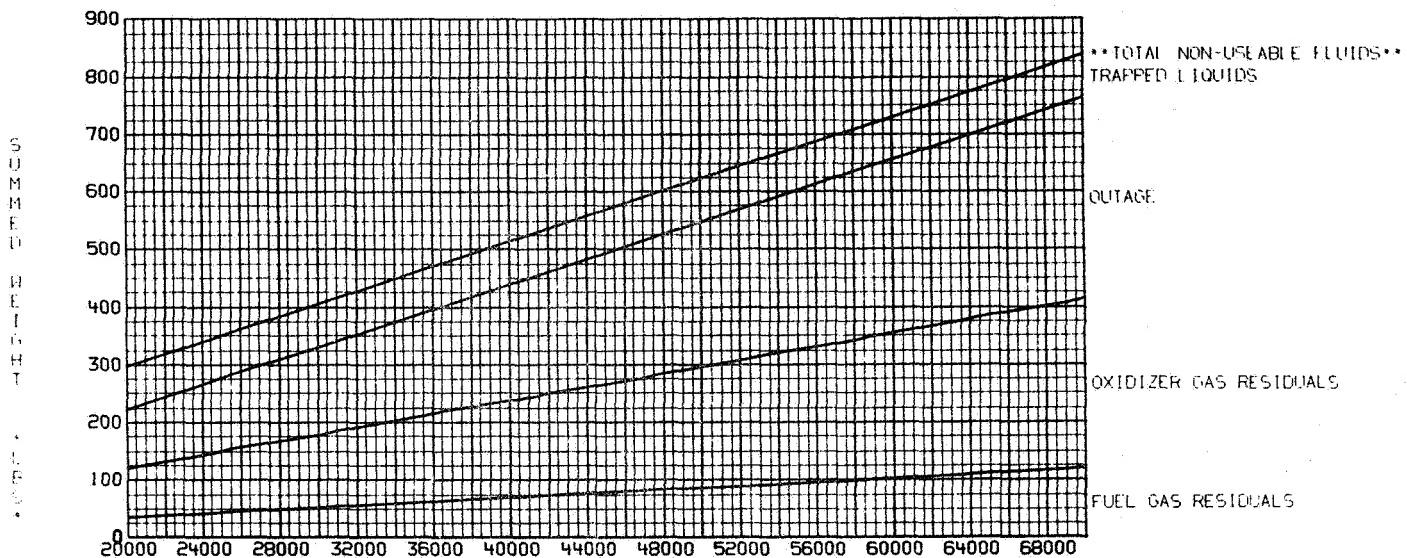


Figure 2-52

NON IMPULSE CONSUMABLES

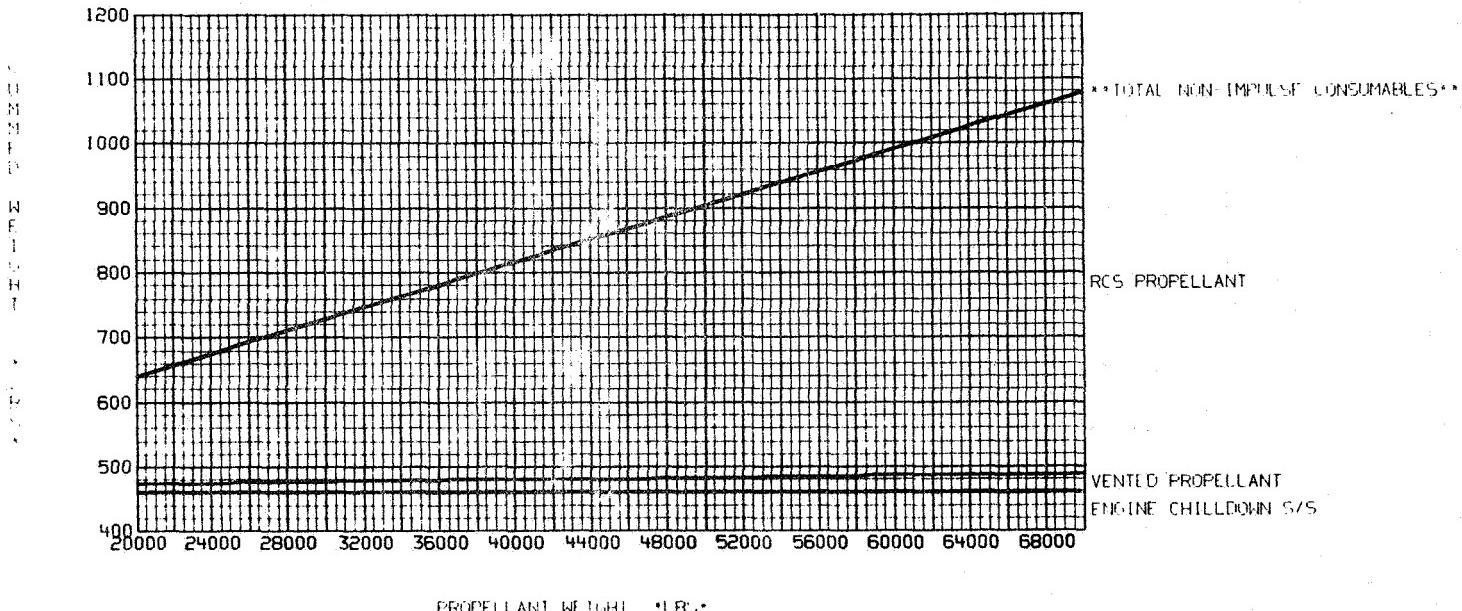


Figure 2-53

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THROU

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

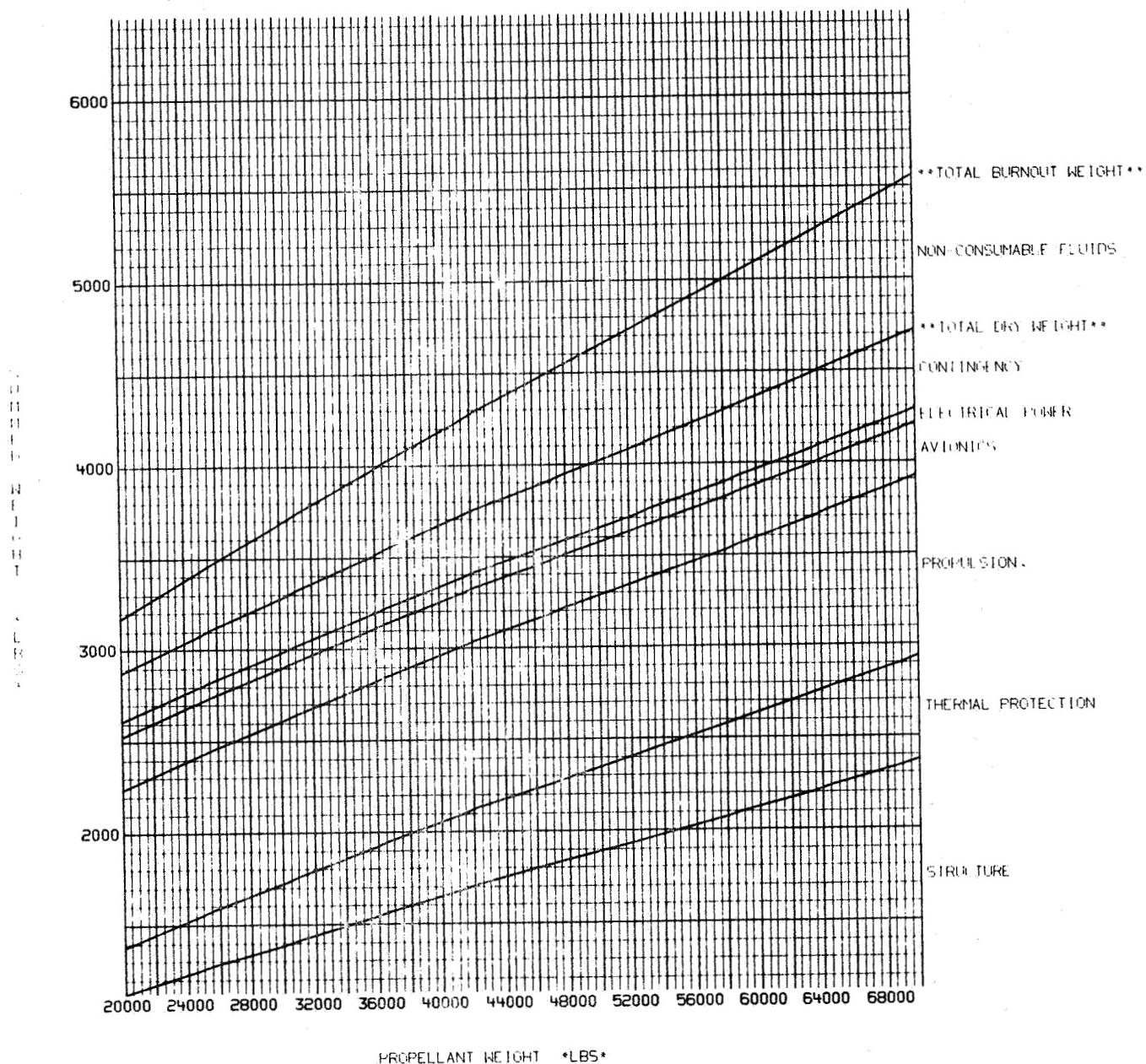


Figure 2-54

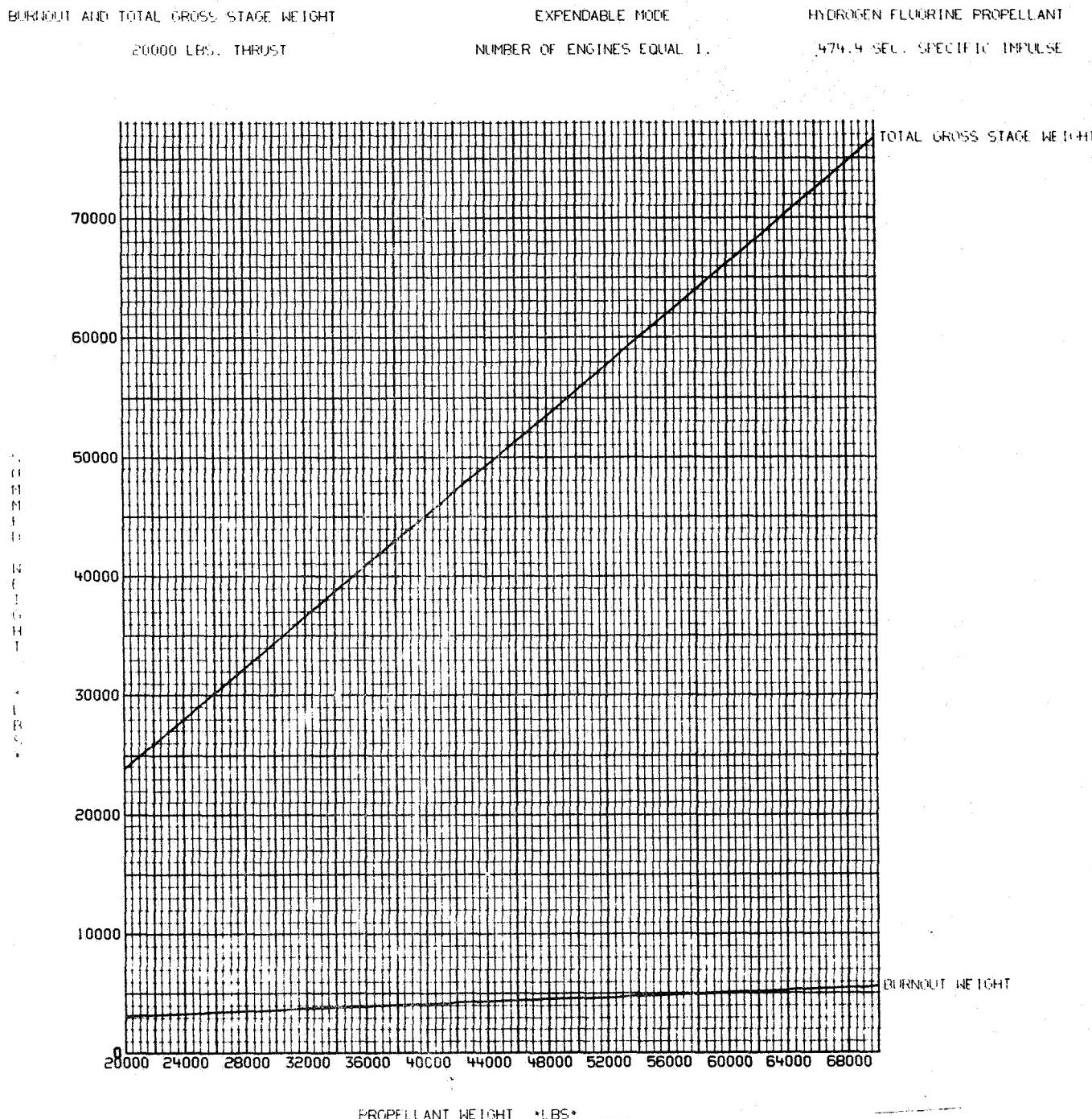


Figure 2-55

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
40000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

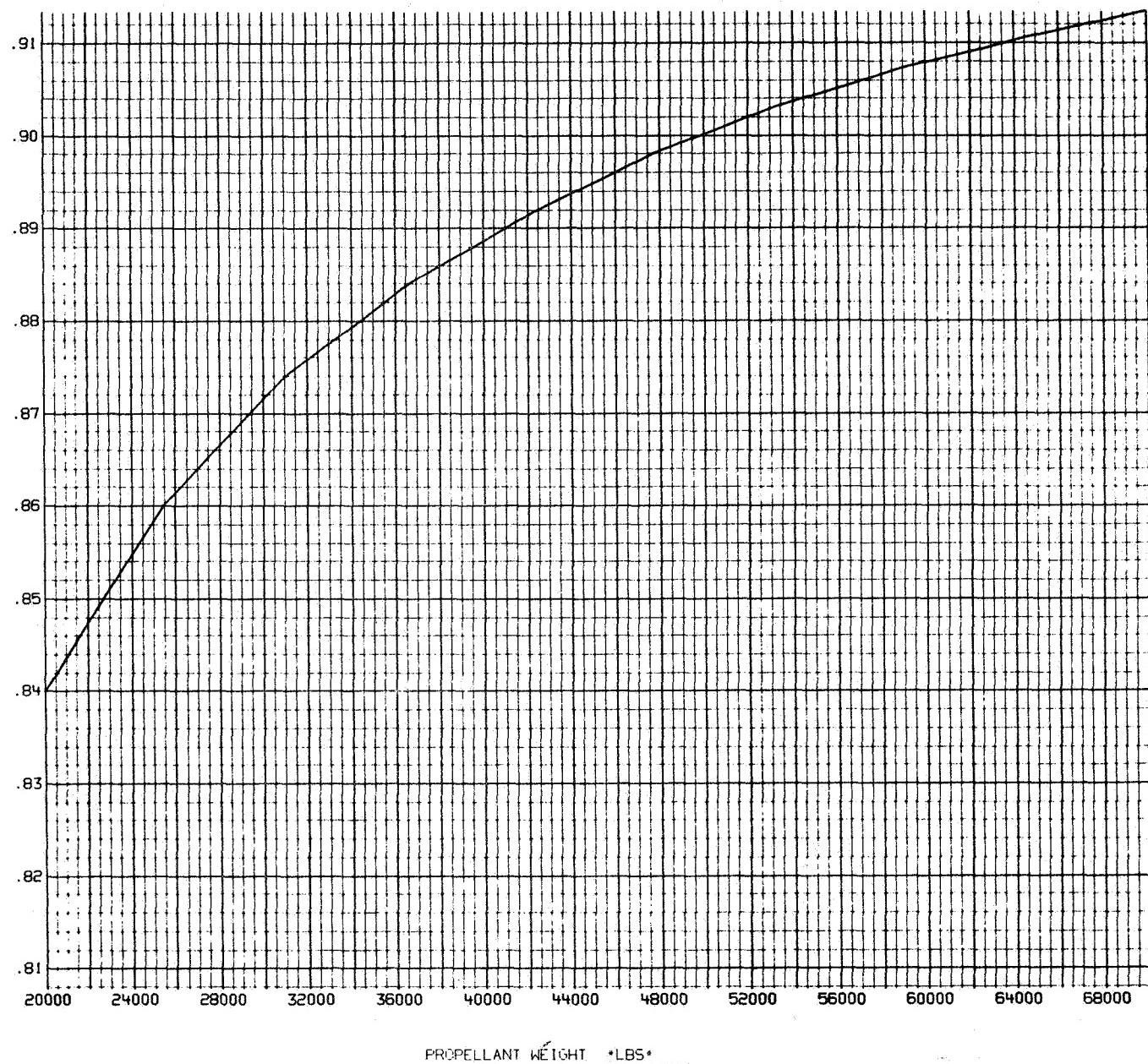


Figure 2-56

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.
20000 LBS. THRUST EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

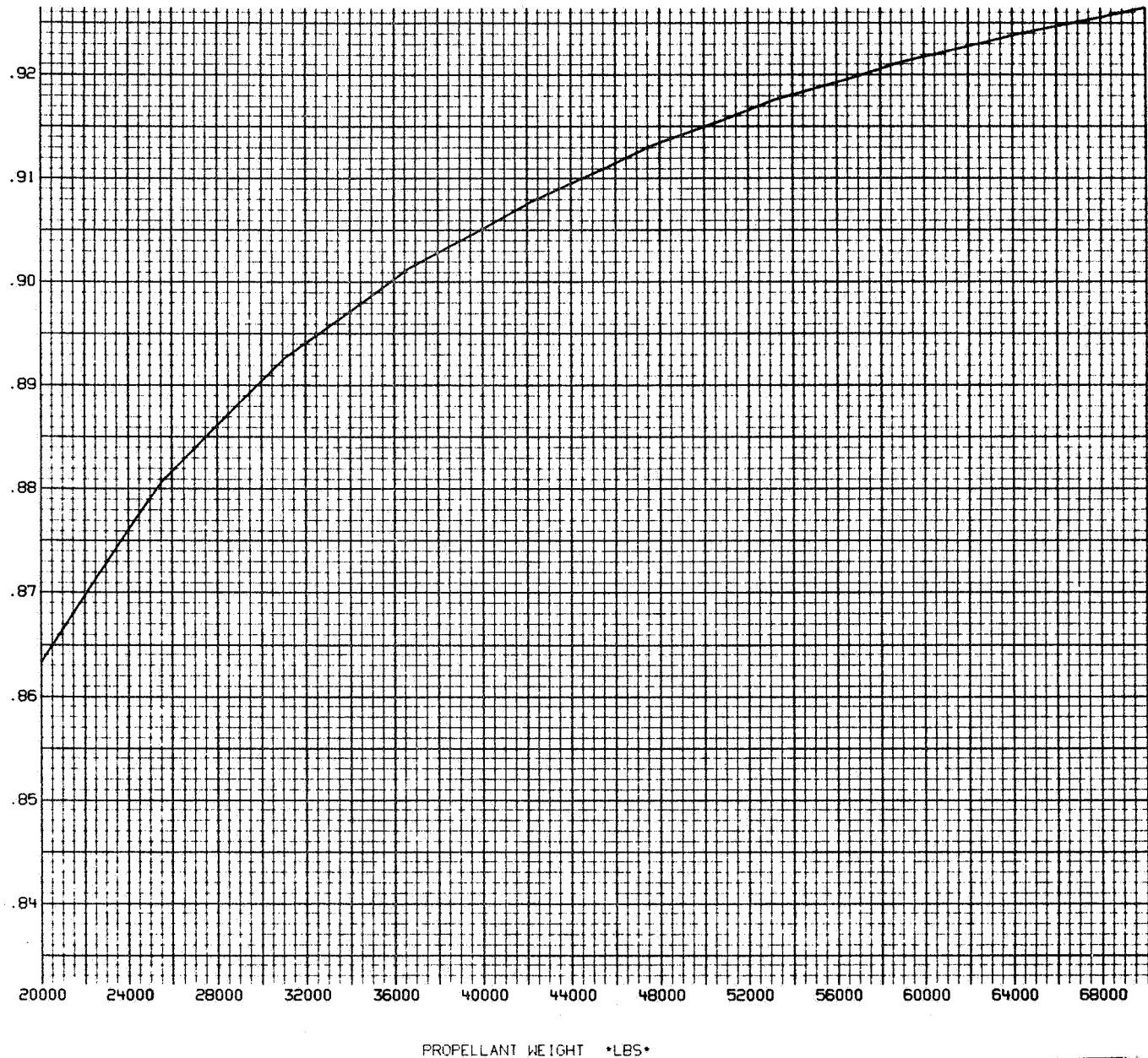


Figure 2-57

STRUCTURE

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

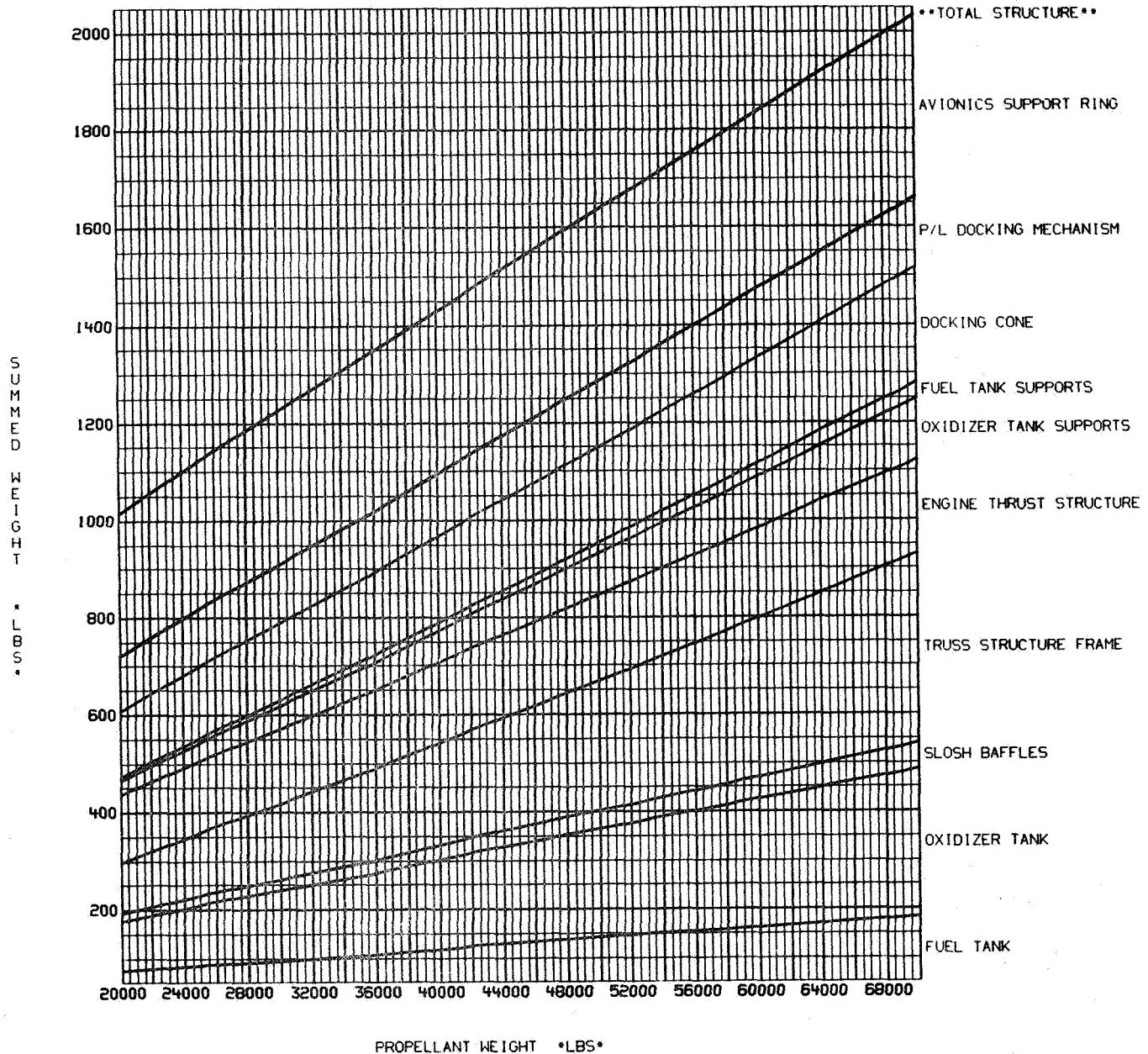


Figure 2-58

REUSEABLE MODE FLOX METHANE PROPELLANT
20000 LBS. THRUST NUMBER OF ENGINES EQUAL 1. 414.0 SEC. SPECIFIC IMPULSE
THERMAL PROTECTION

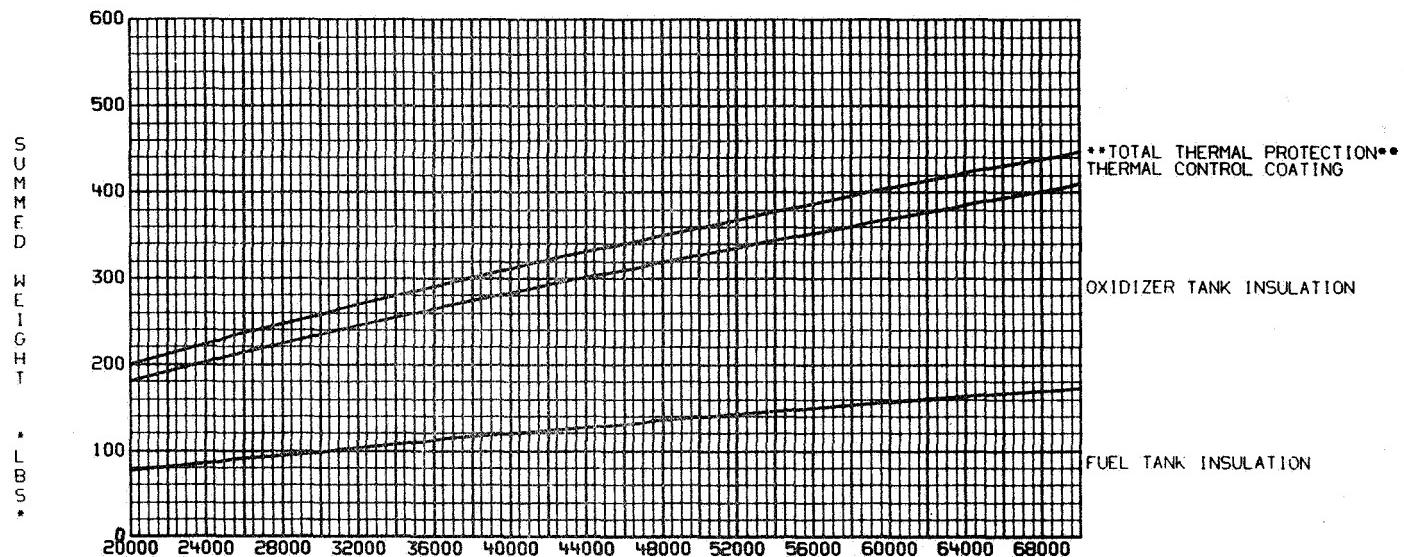


Figure 2-59

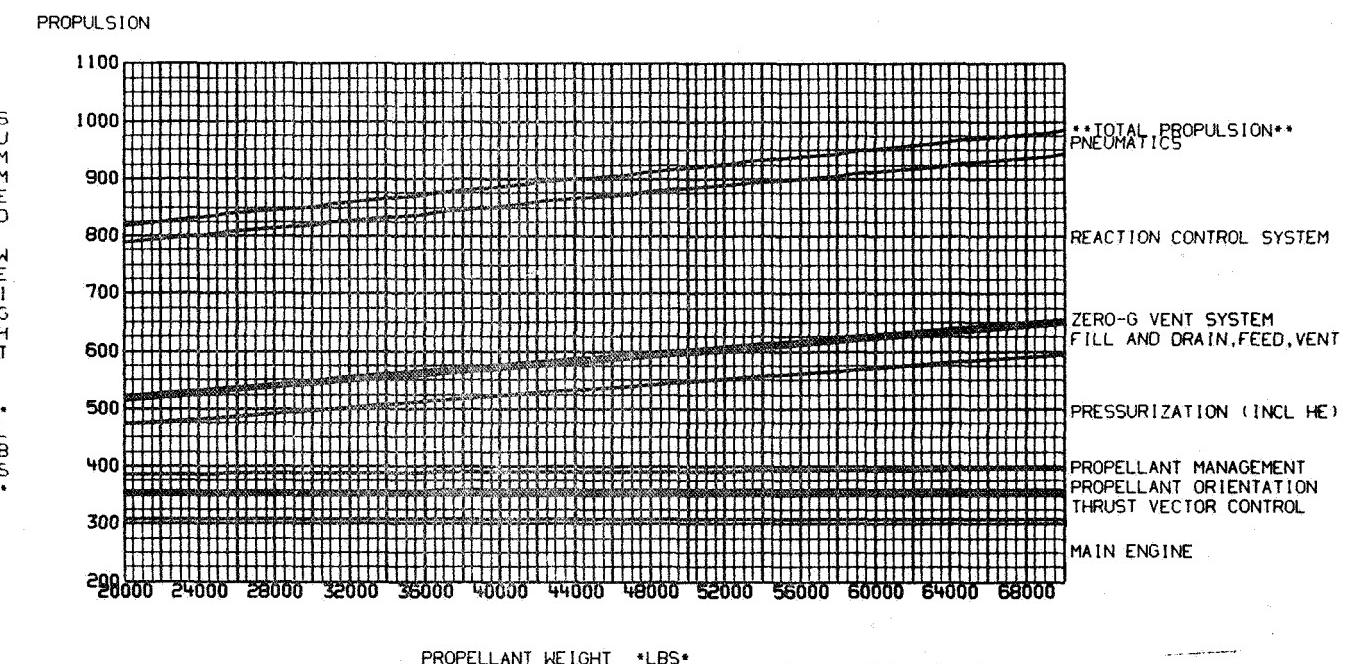


Figure 2-60

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

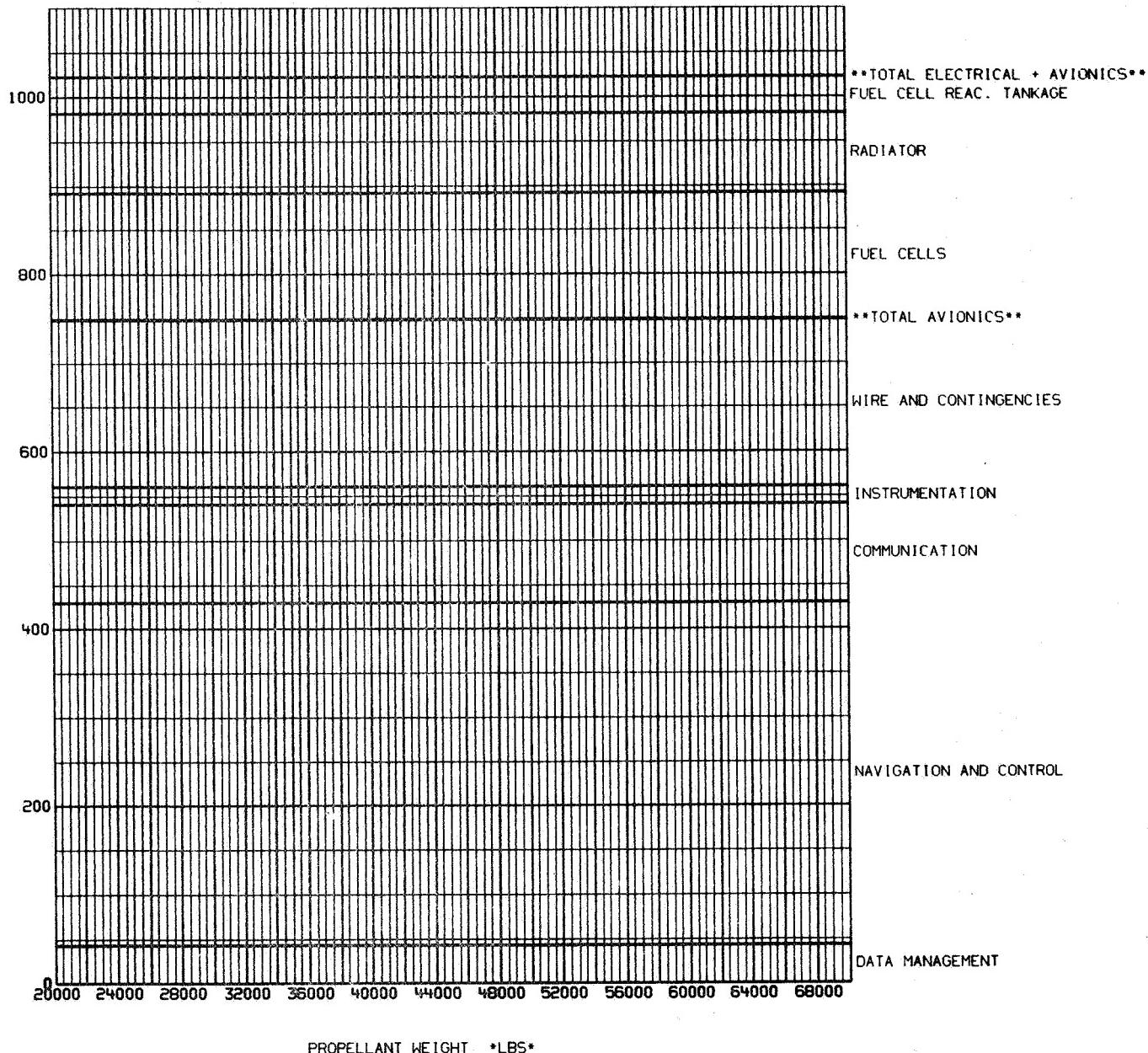


Figure 2-61

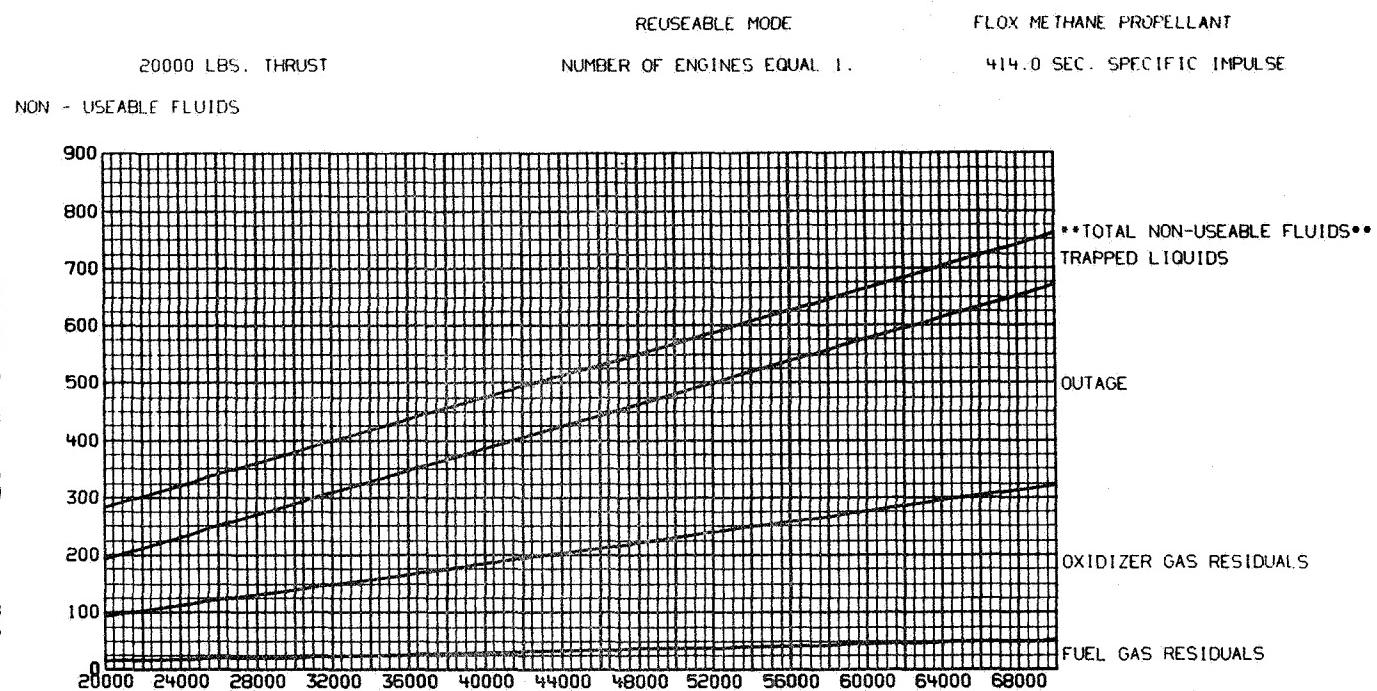


Figure 2-62

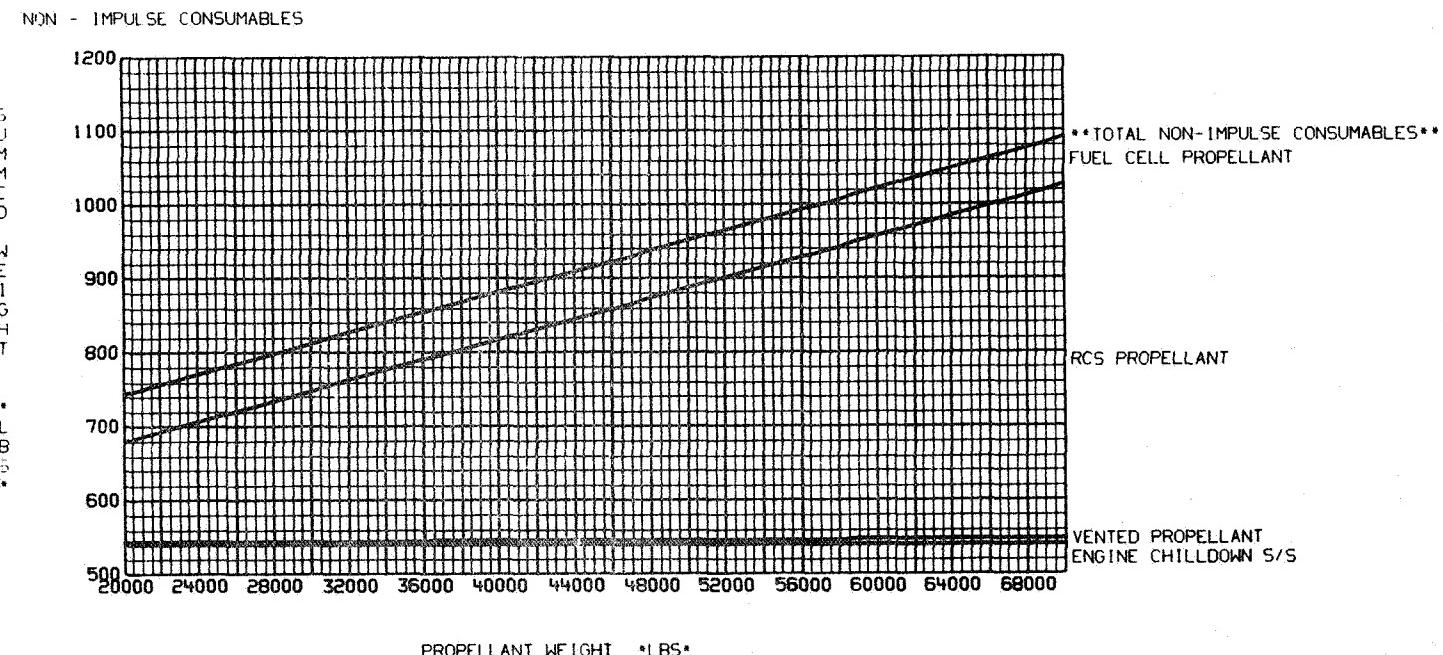


Figure 2-63

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

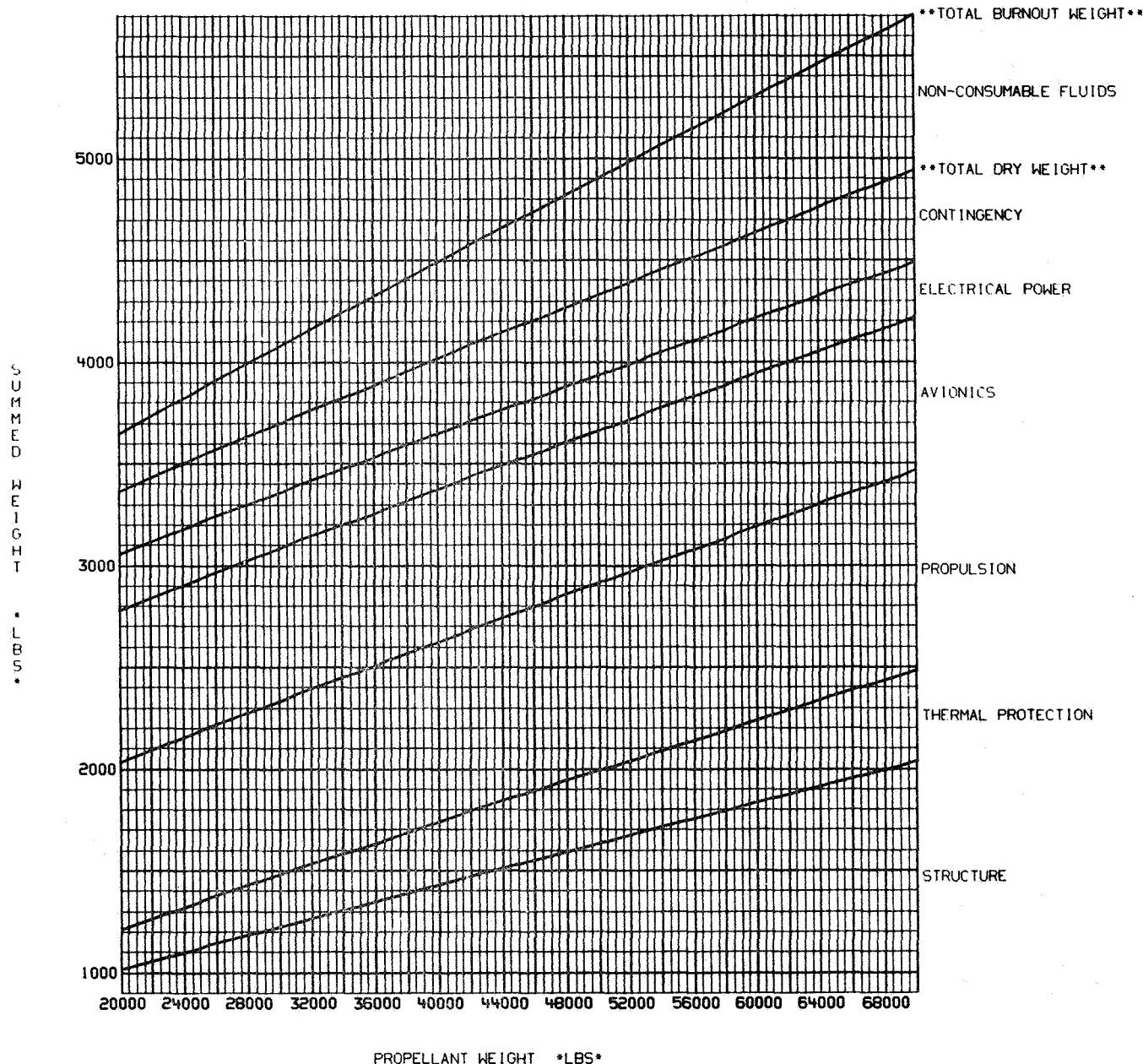


Figure 2-64

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

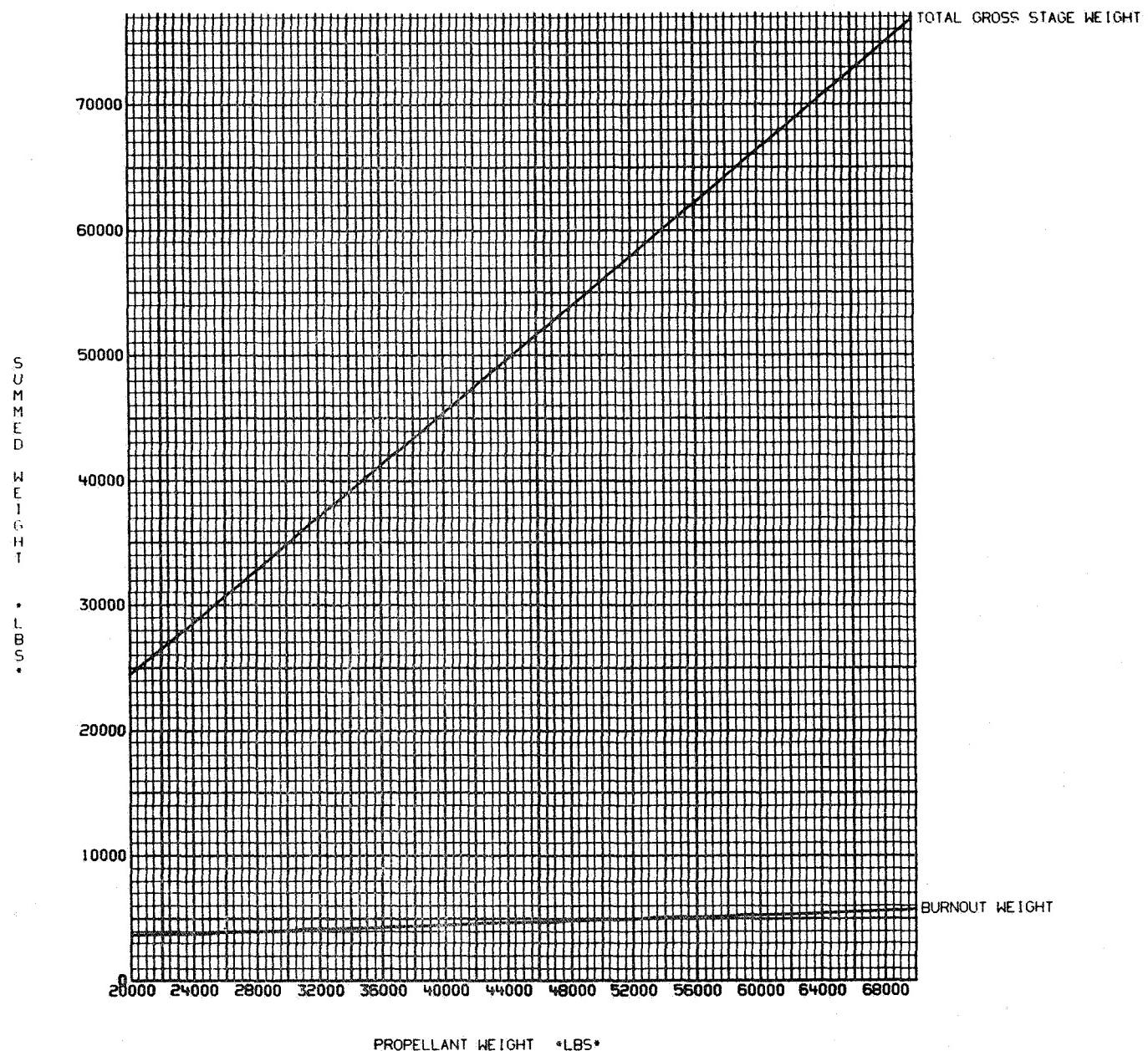


Figure 2-65

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

L
A
M
B
D
A

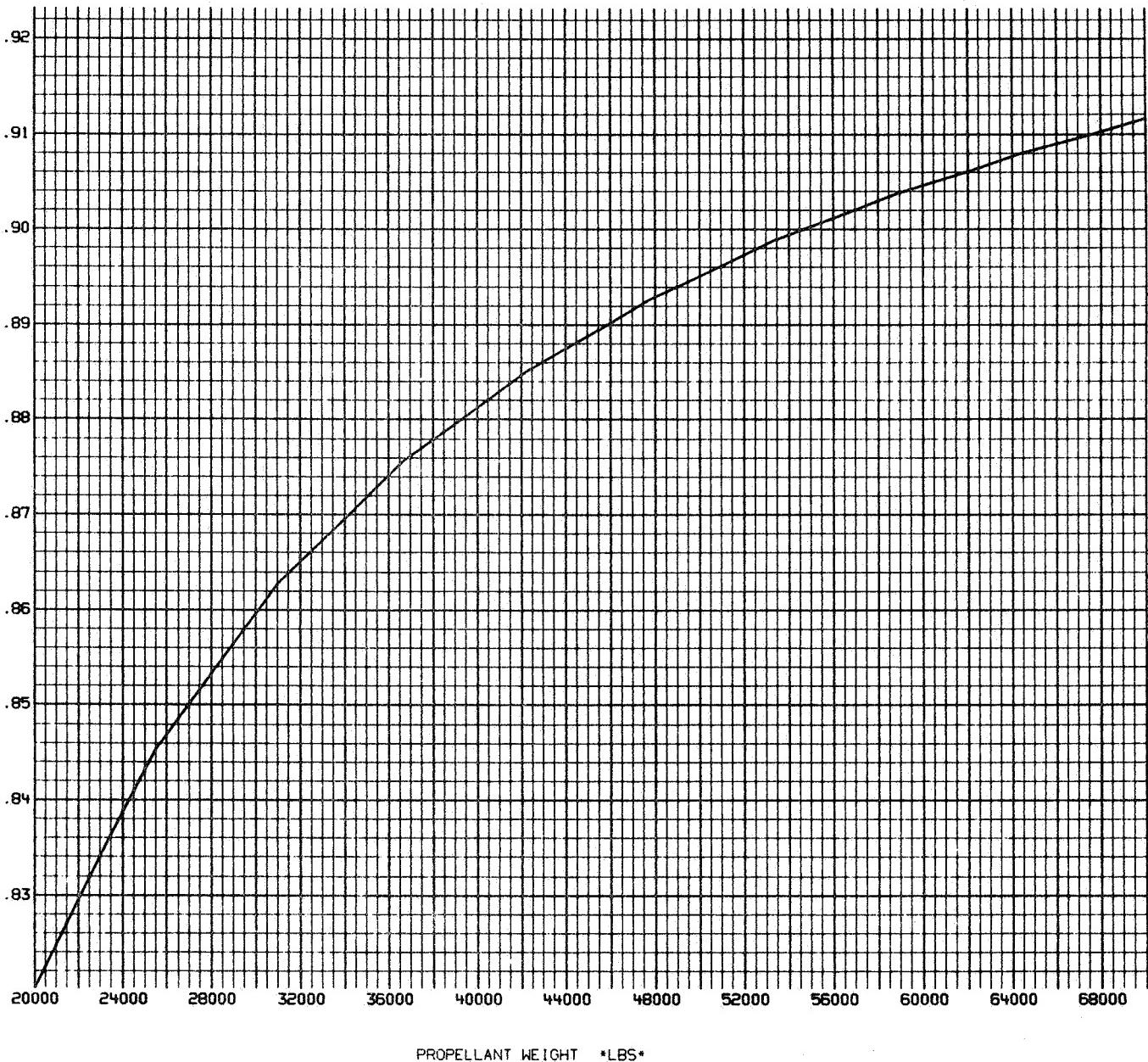
P
R
I
M
E

Figure 2-66

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. REUSABLE MODE

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

L
A
M
B
D
A

P
R
I
M
E

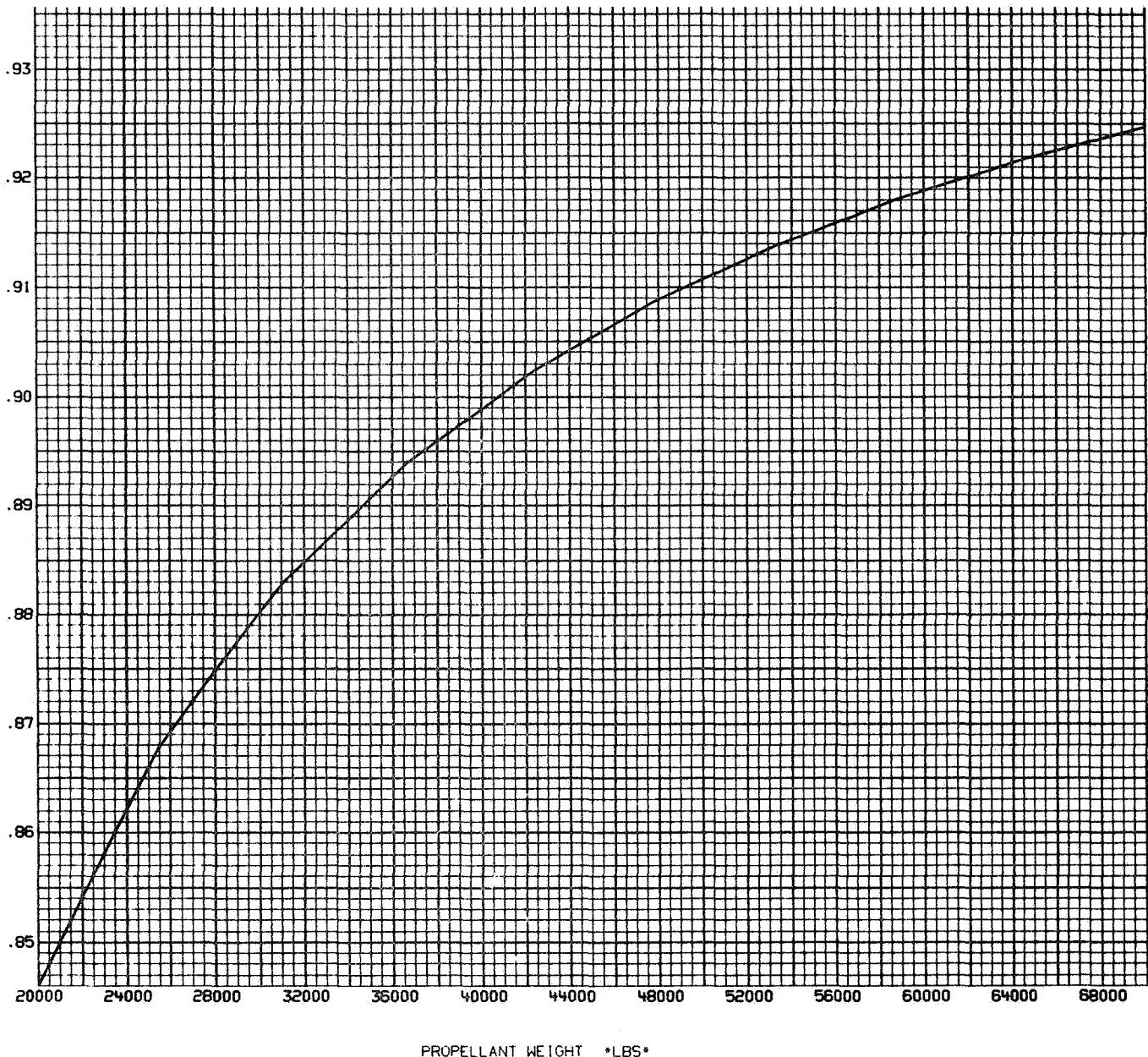


Figure 2-67

OXIDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

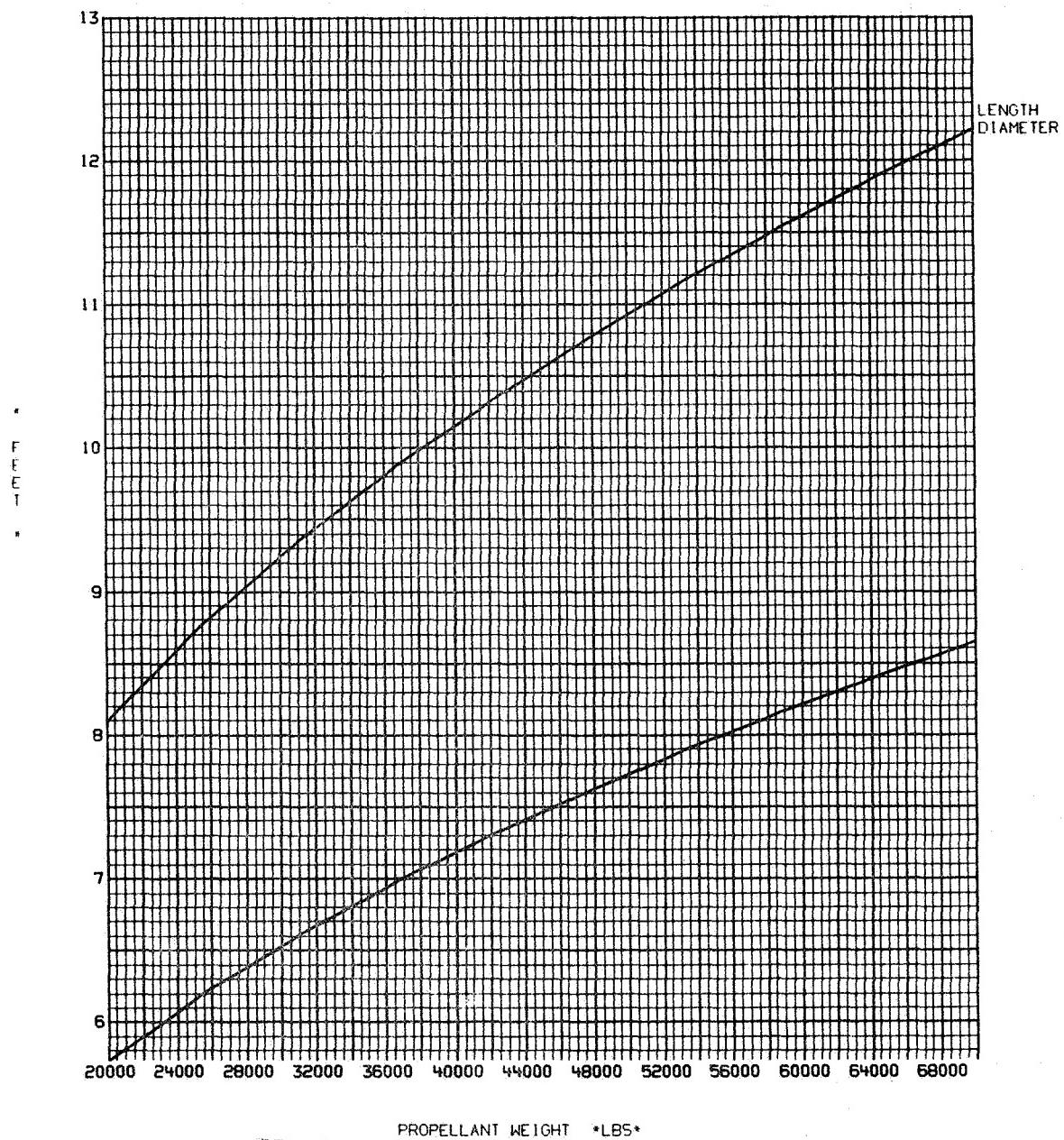


Figure 2-68

OXIDIZER TANK

20000 LBS. THRUST

FLOX METHANE PROPELLANT

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

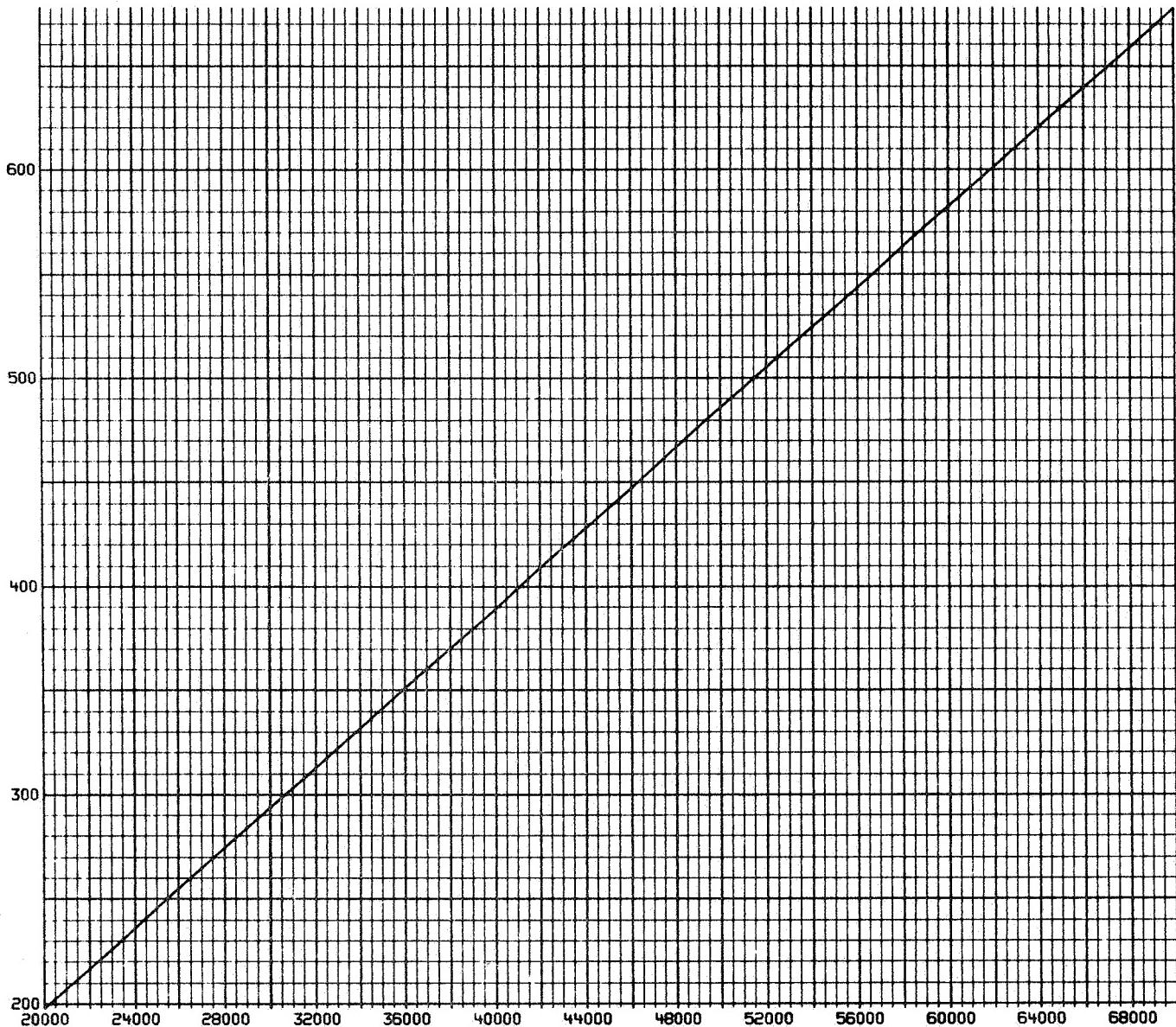


Figure 2-69

OXIDIZER TANK

20000 LBS. THRUST

FLOX METHANE PROPELLANT

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

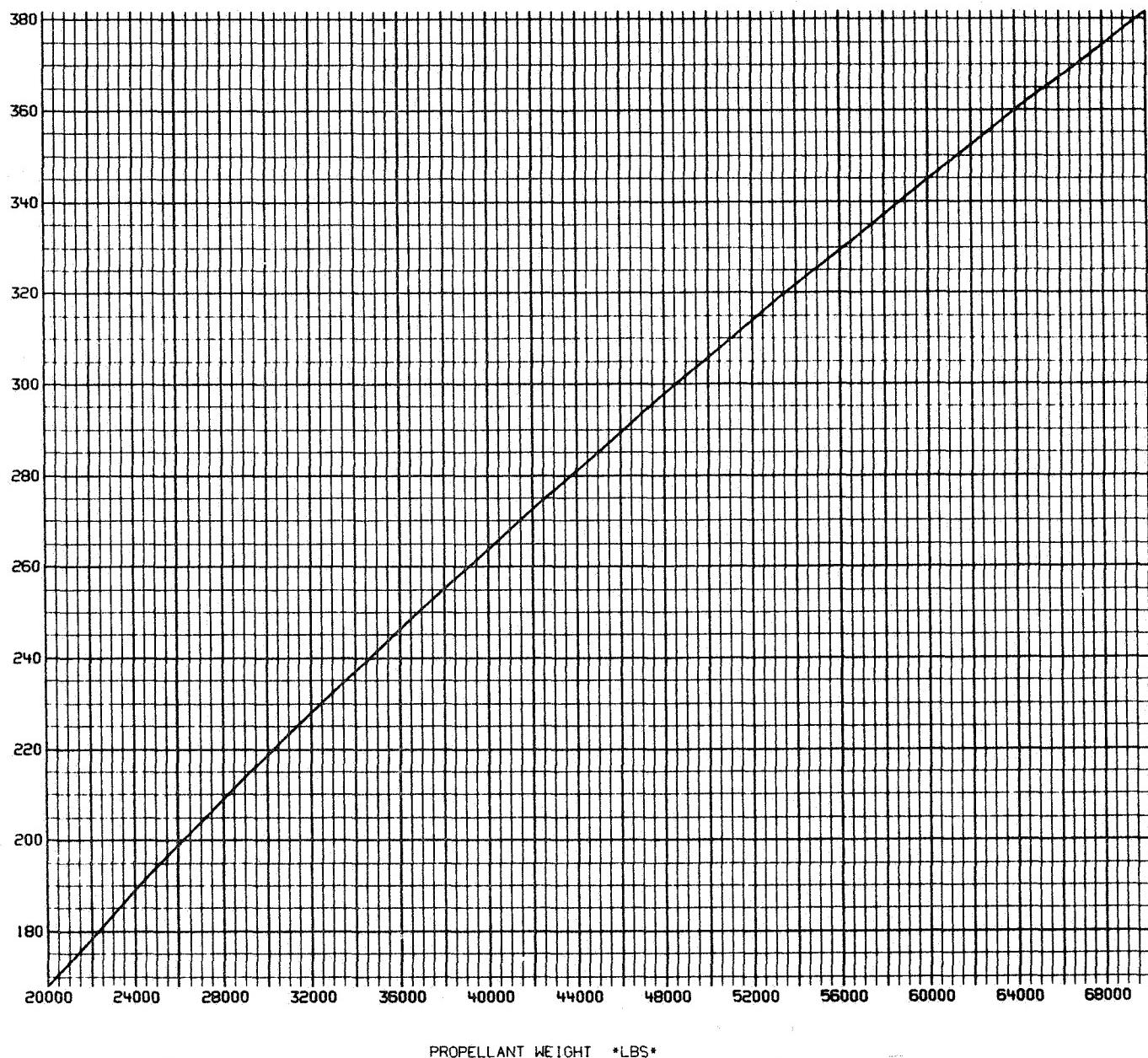
A
R
E
A
•
F
T
2
•

Figure 2-70

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX/METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

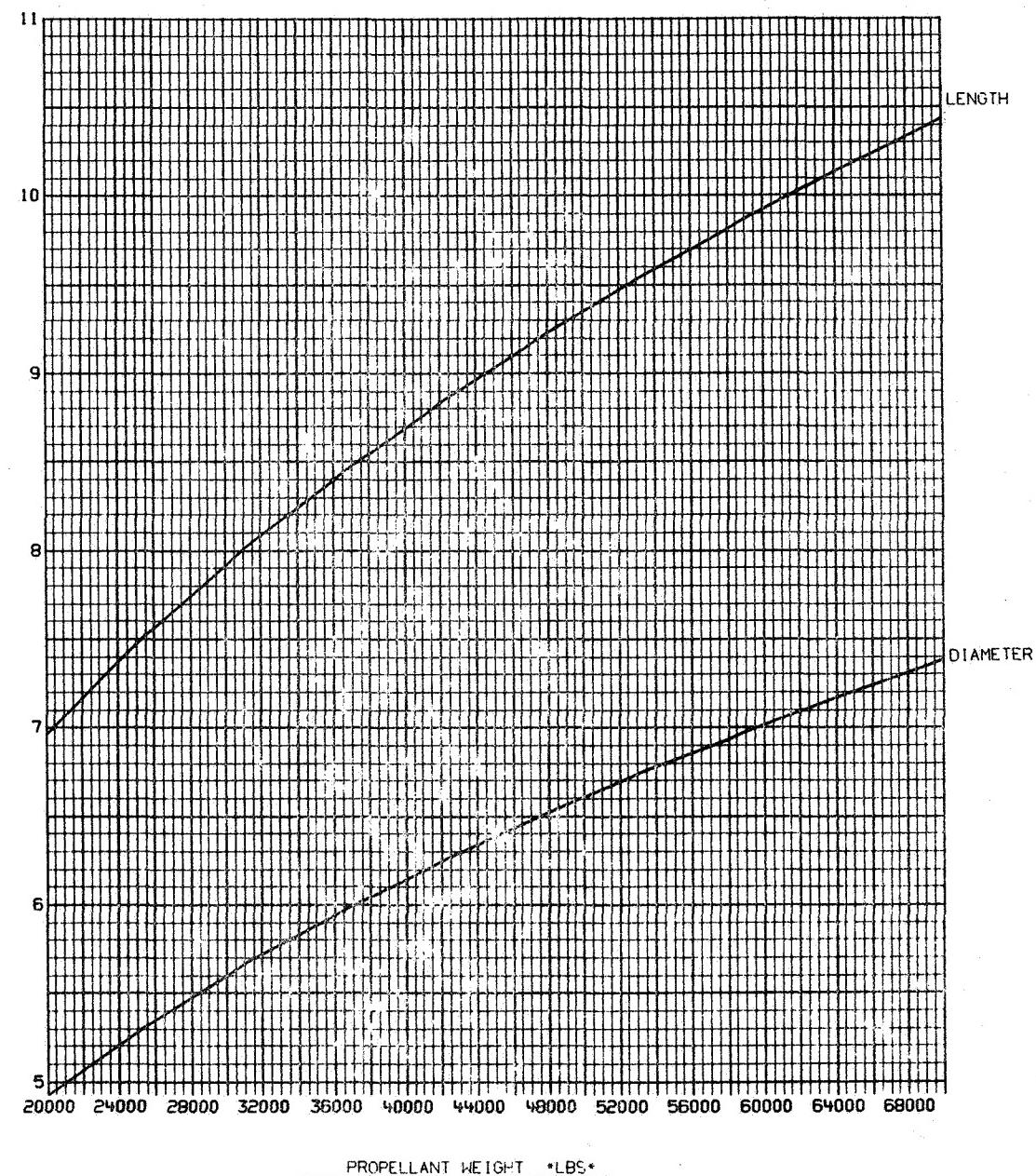


Figure 2-71

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

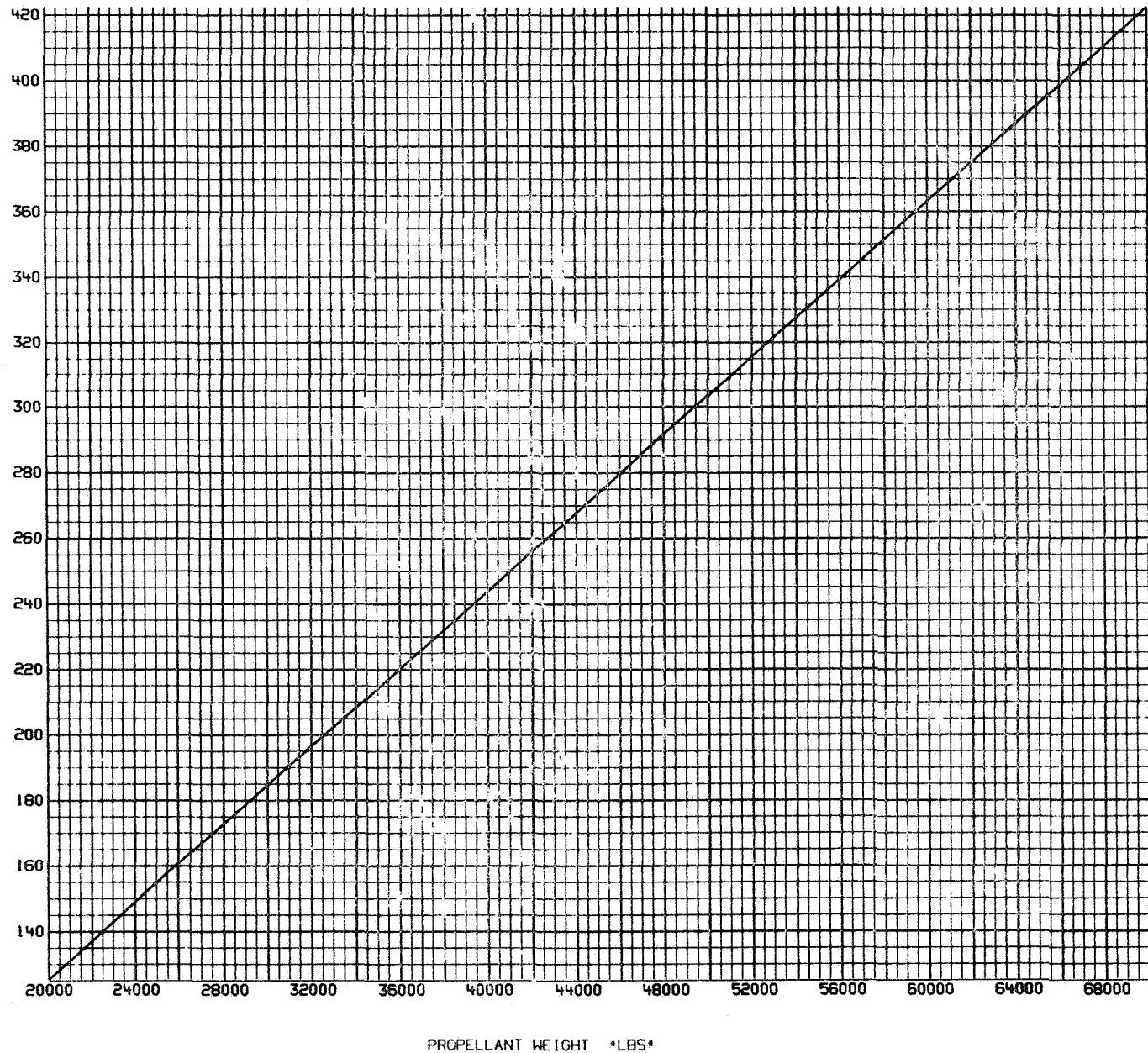


Figure 2-72

FULL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

A
R
E
A
•
F
T
2
•

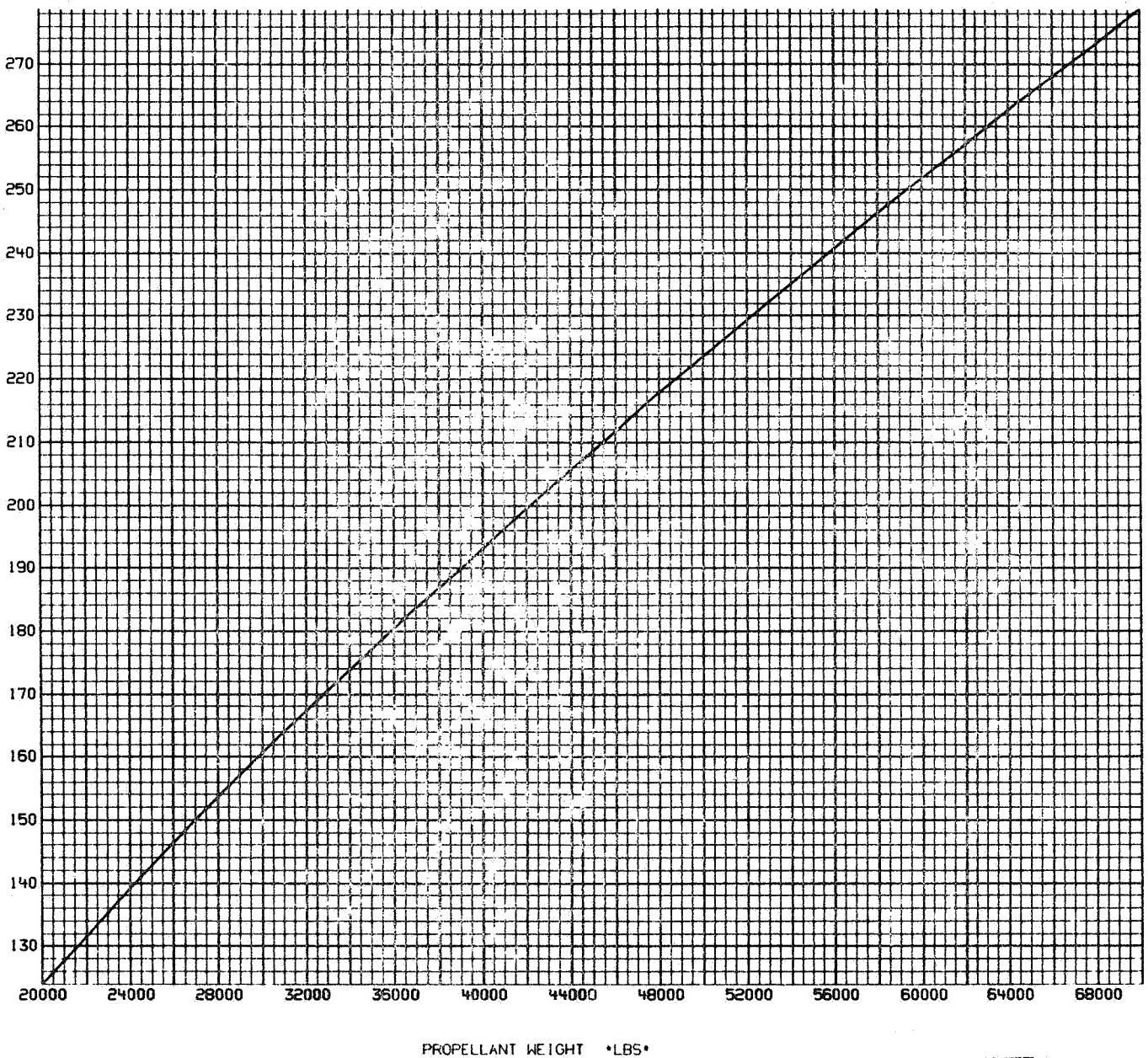


Figure 2-73

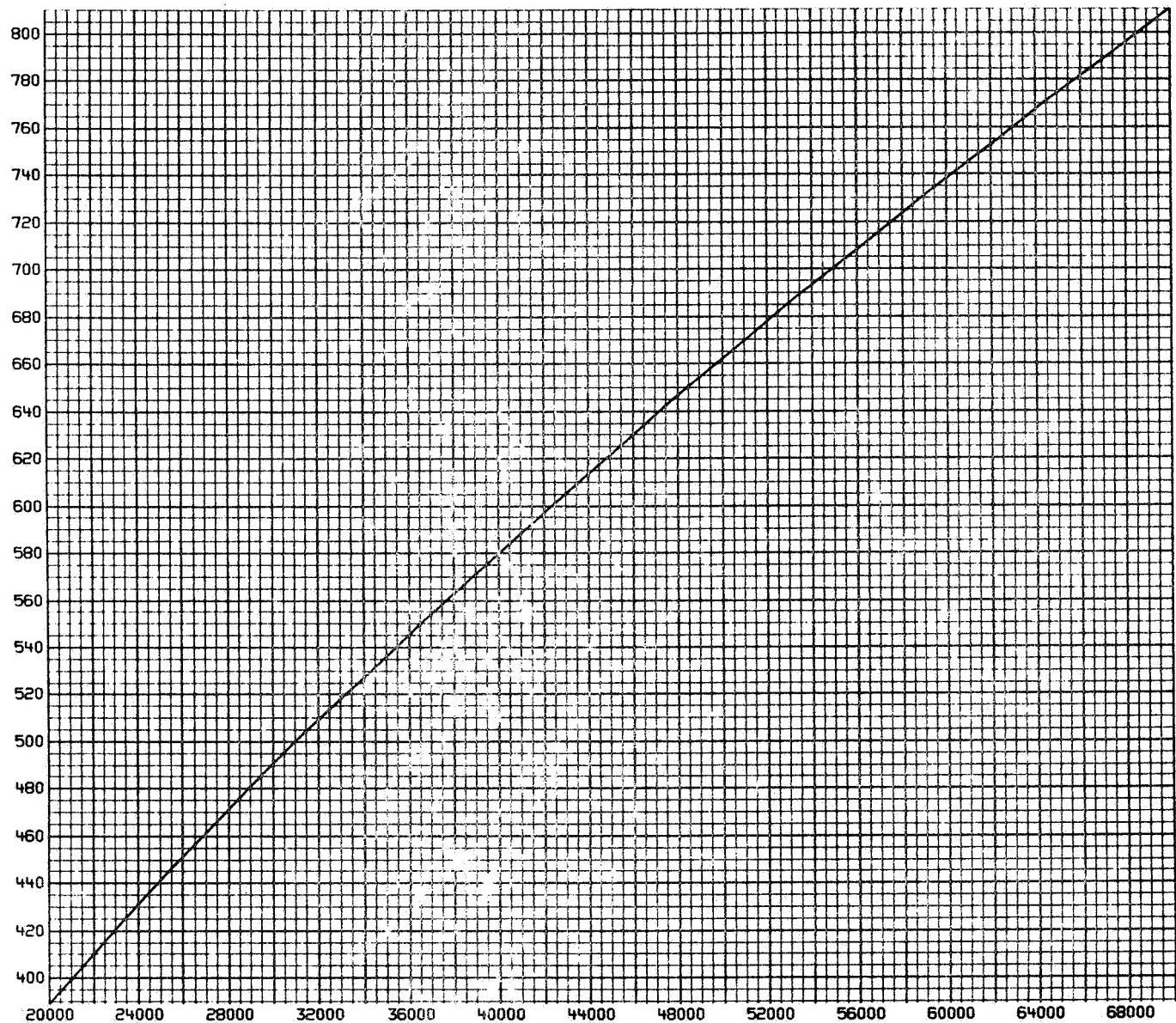
AREA OF CYLINDER + CONE

20000 LBS. THRUST

FLUX METHANE PROPELLANT

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE



PROPELLANT WEIGHT *LBS*

Figure 2-74

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

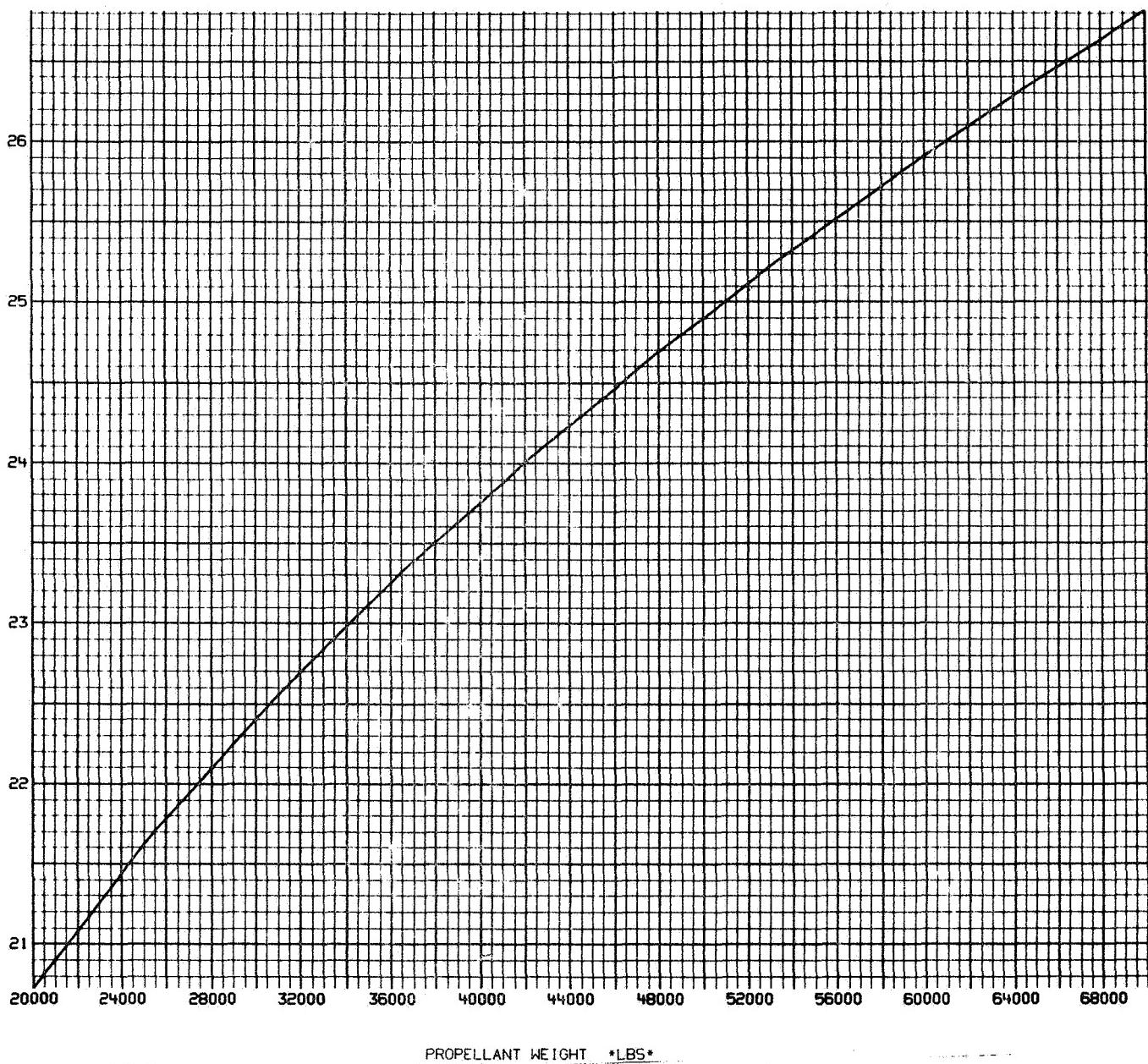


Figure 2-75

STRUCTURE

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

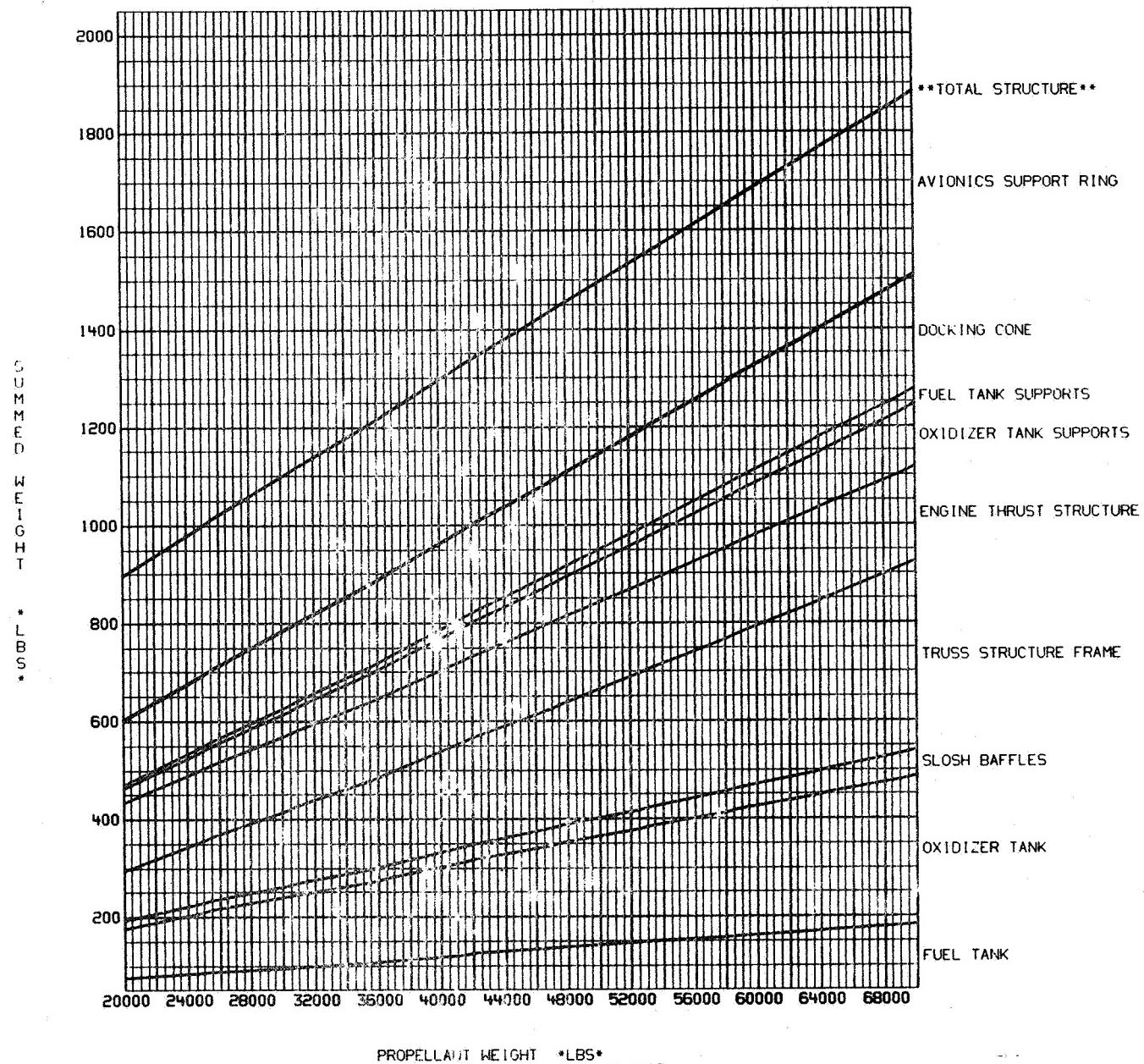


Figure 2-76

EXPENDABLE MODE FLOX METHANE PROPELLANT
20000 LBS. THRUST NUMBER OF ENGINES EQUAL 1. 414.0 SEC. SPECIFIC IMPULSE
THERMAL PROTECTION

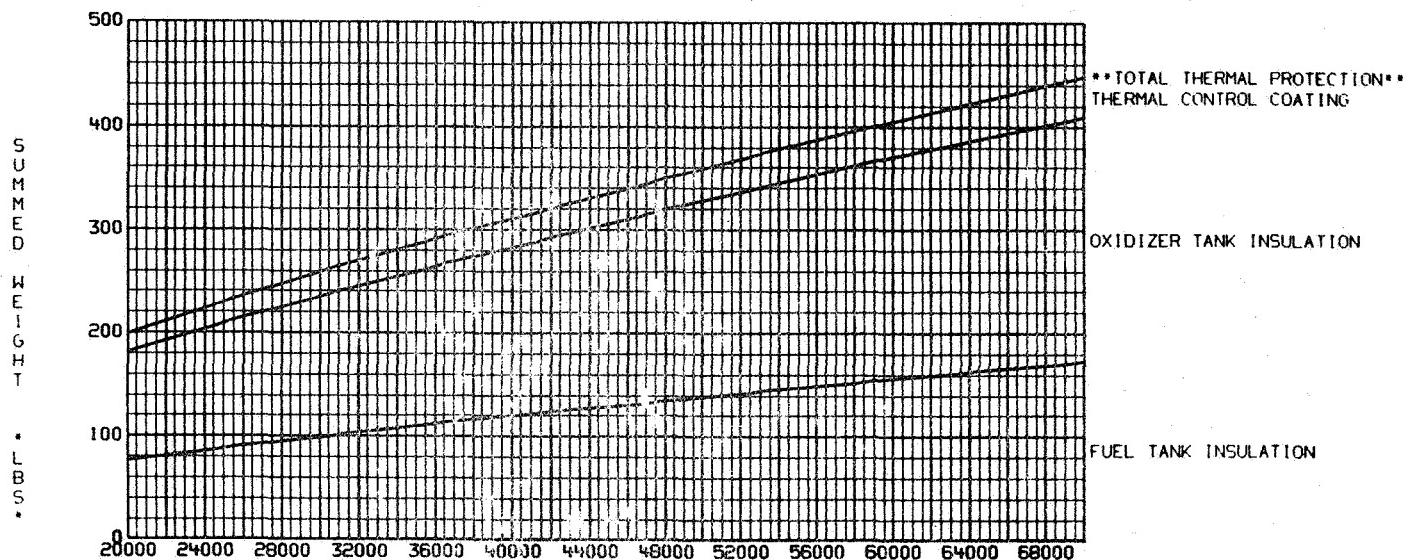


Figure 2-77

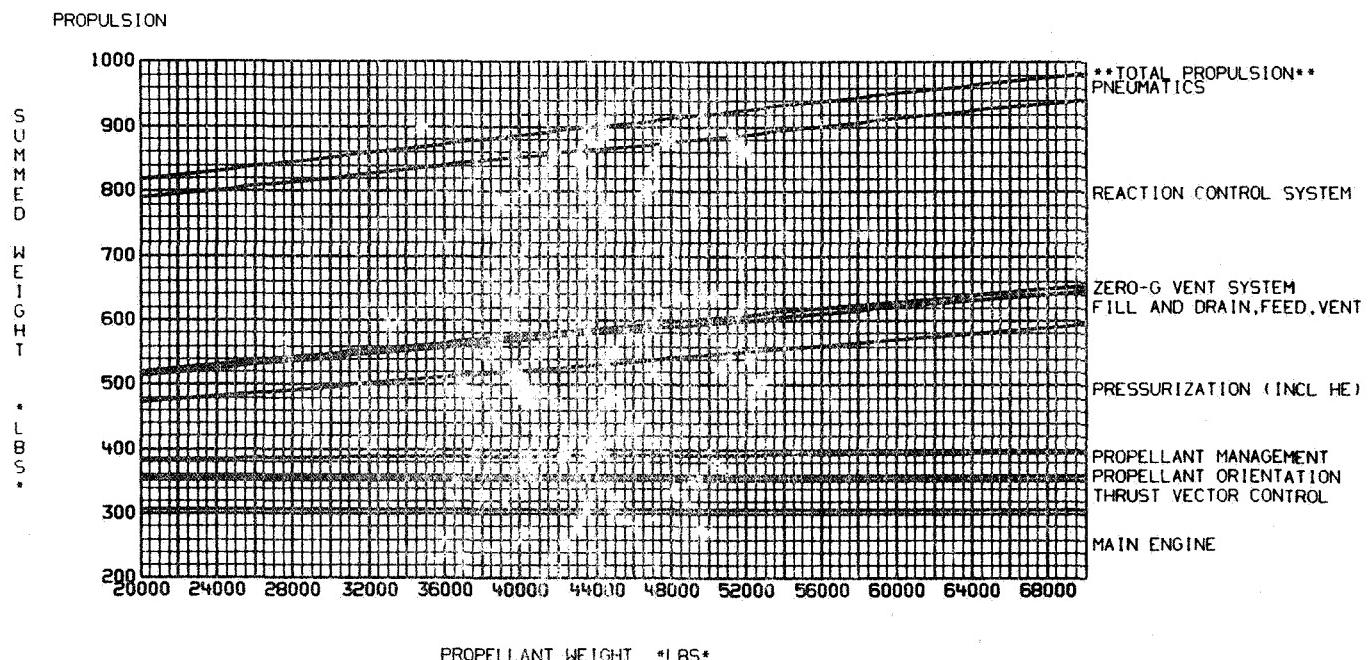


Figure 2-69

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

SUMMED WEIGHT • LBS *

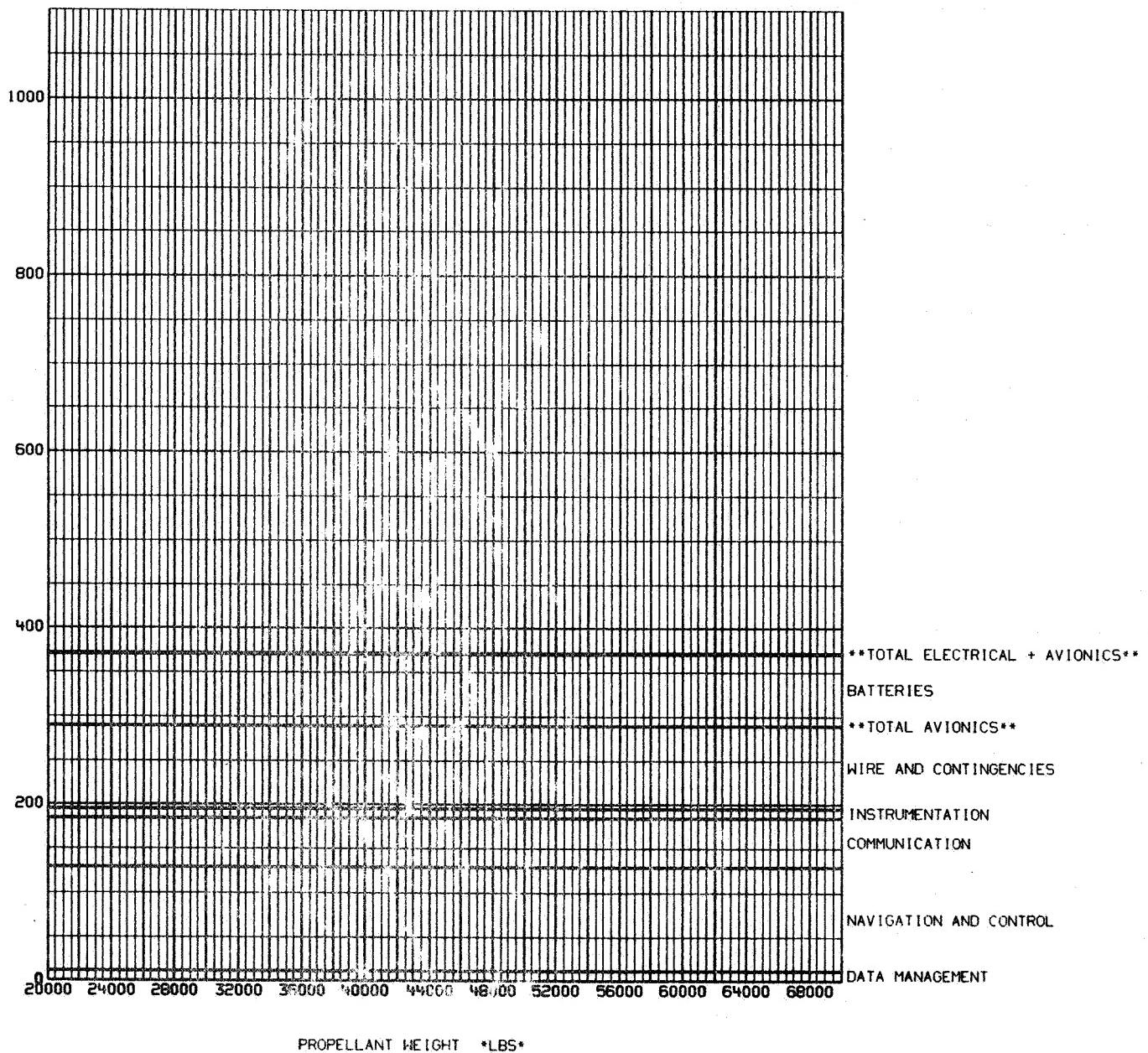


Figure 2-79

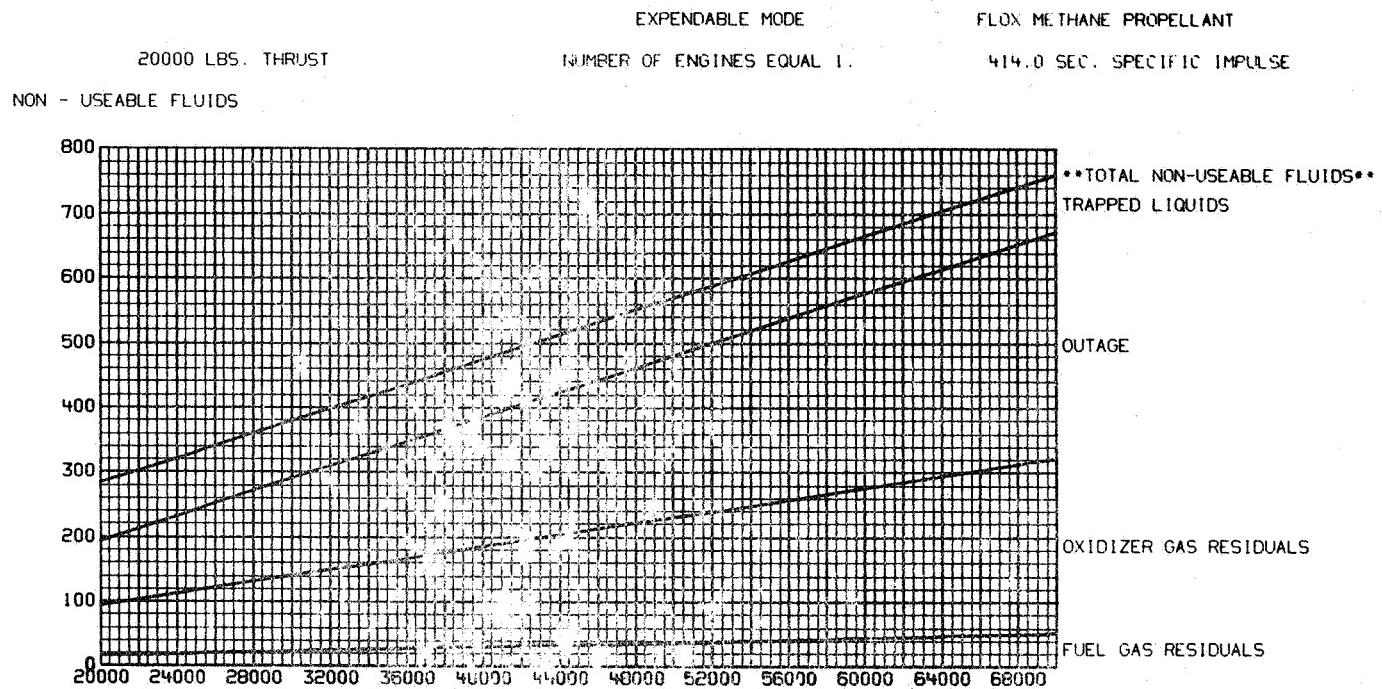


Figure 2-80

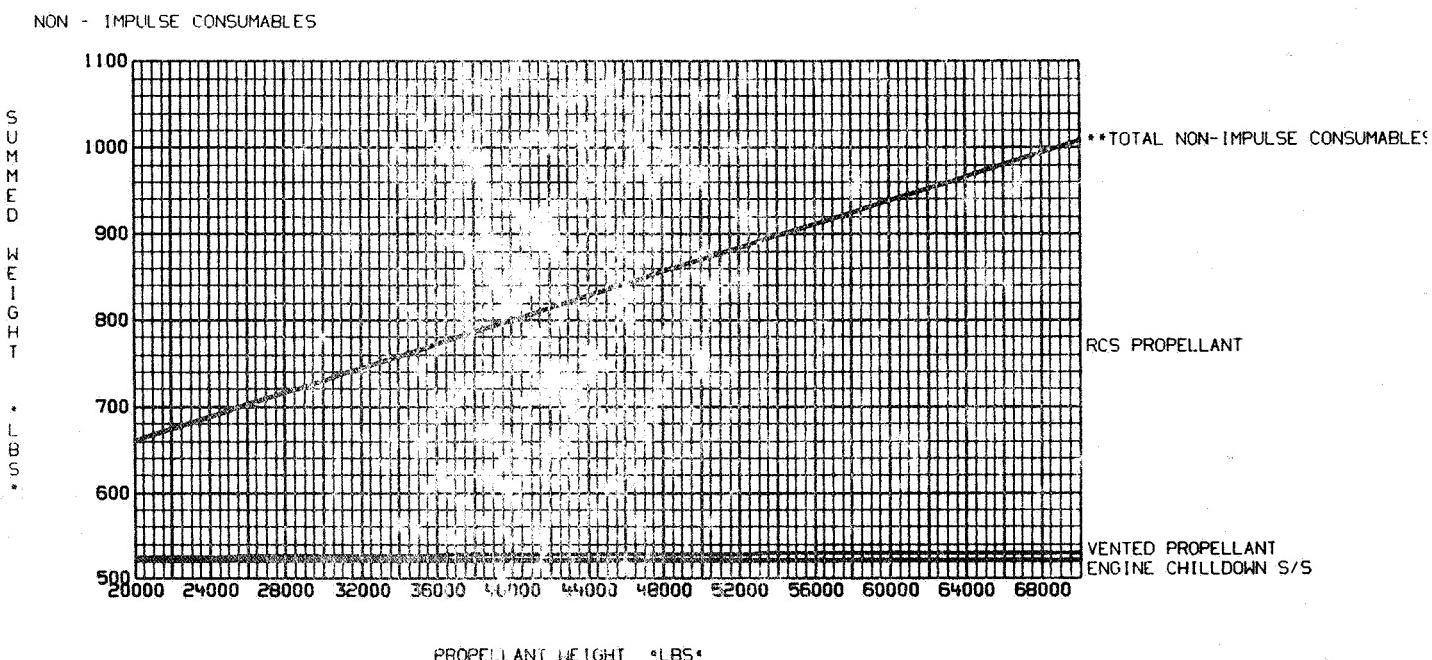


Figure 2-81

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX/METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

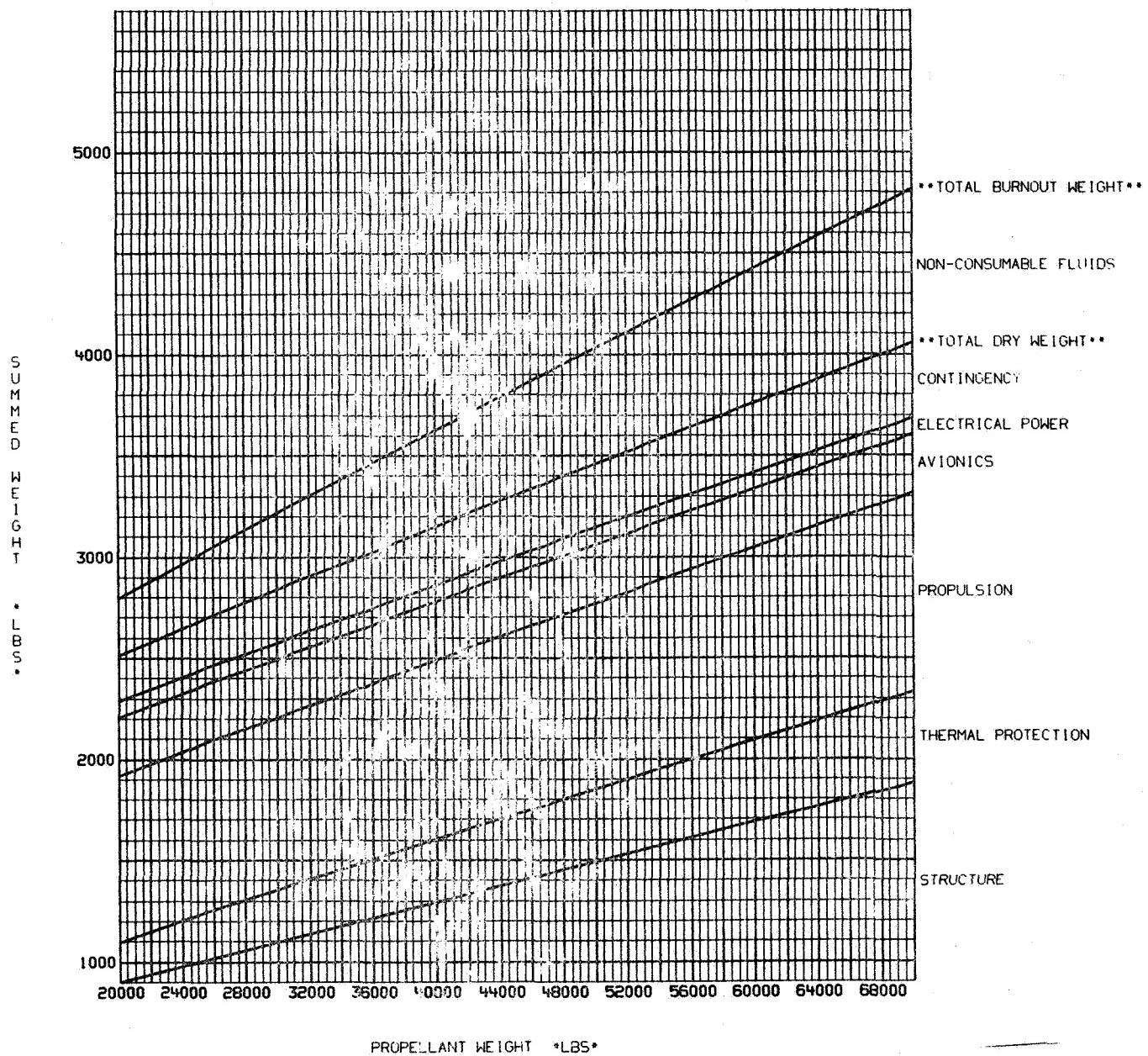


Figure 2-82

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

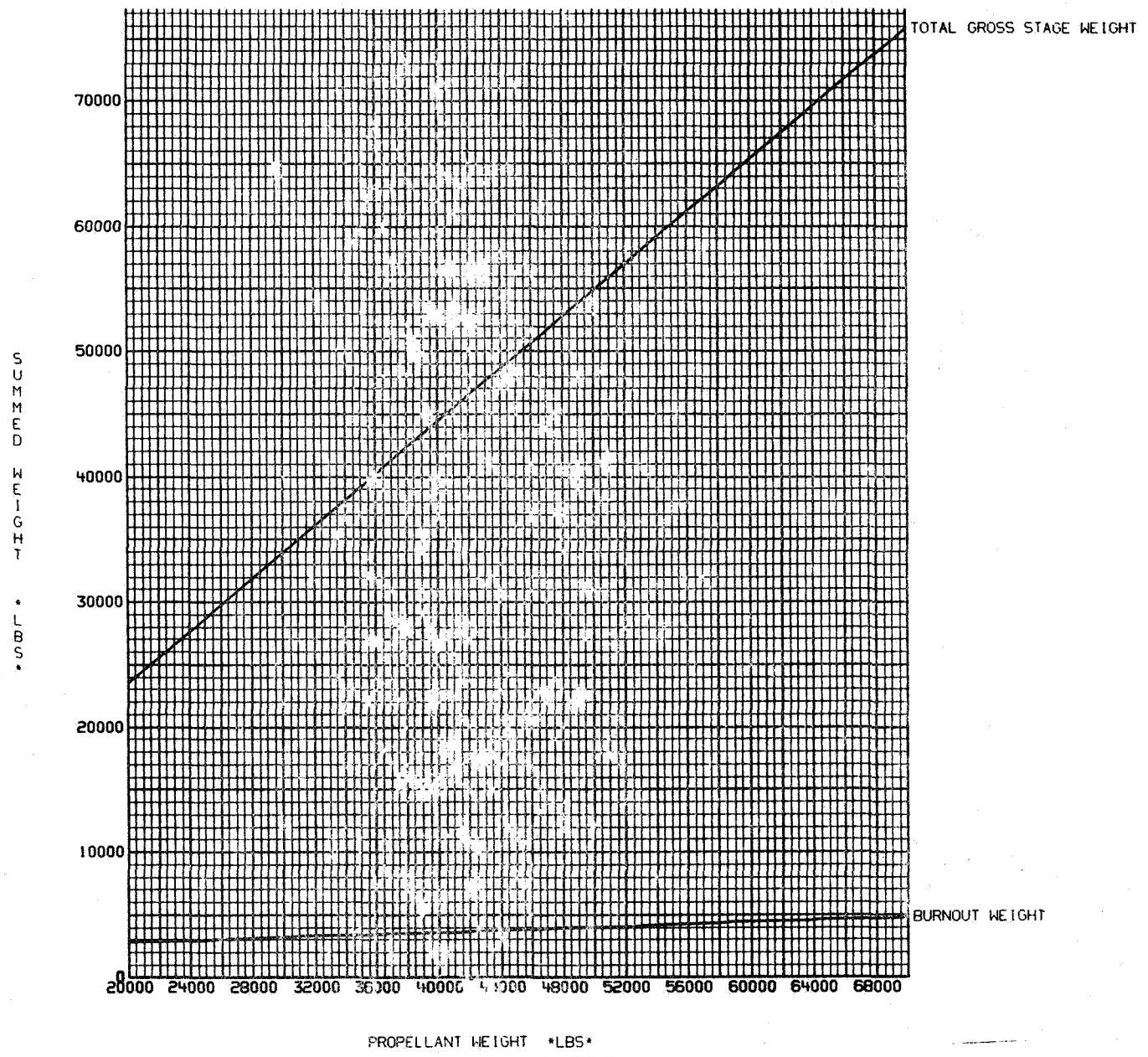


Figure 2-83

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

L
A
M
B
A

P
R
I
M
E

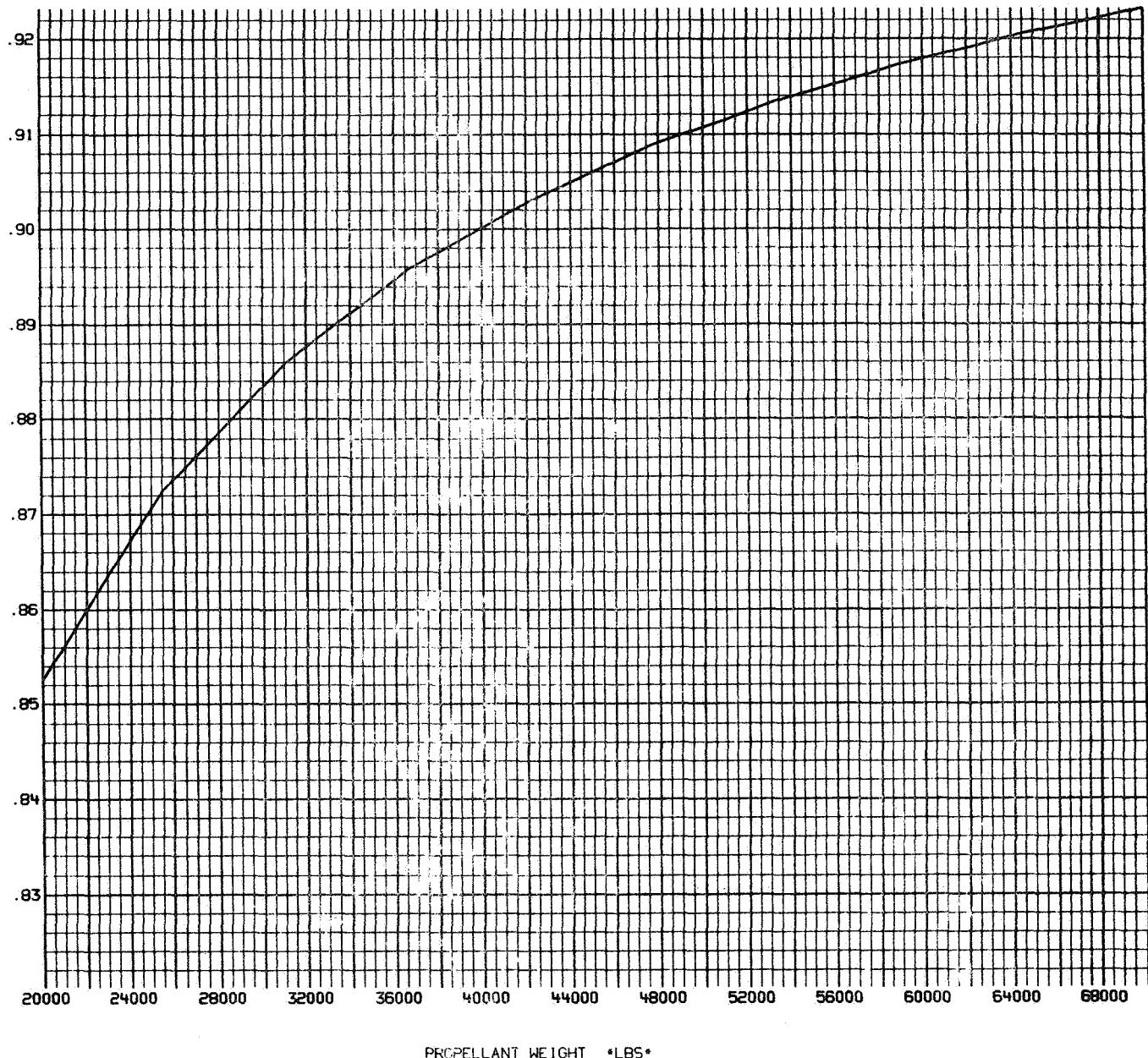


Figure 2-84

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. EXPENDABLE MODE
20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

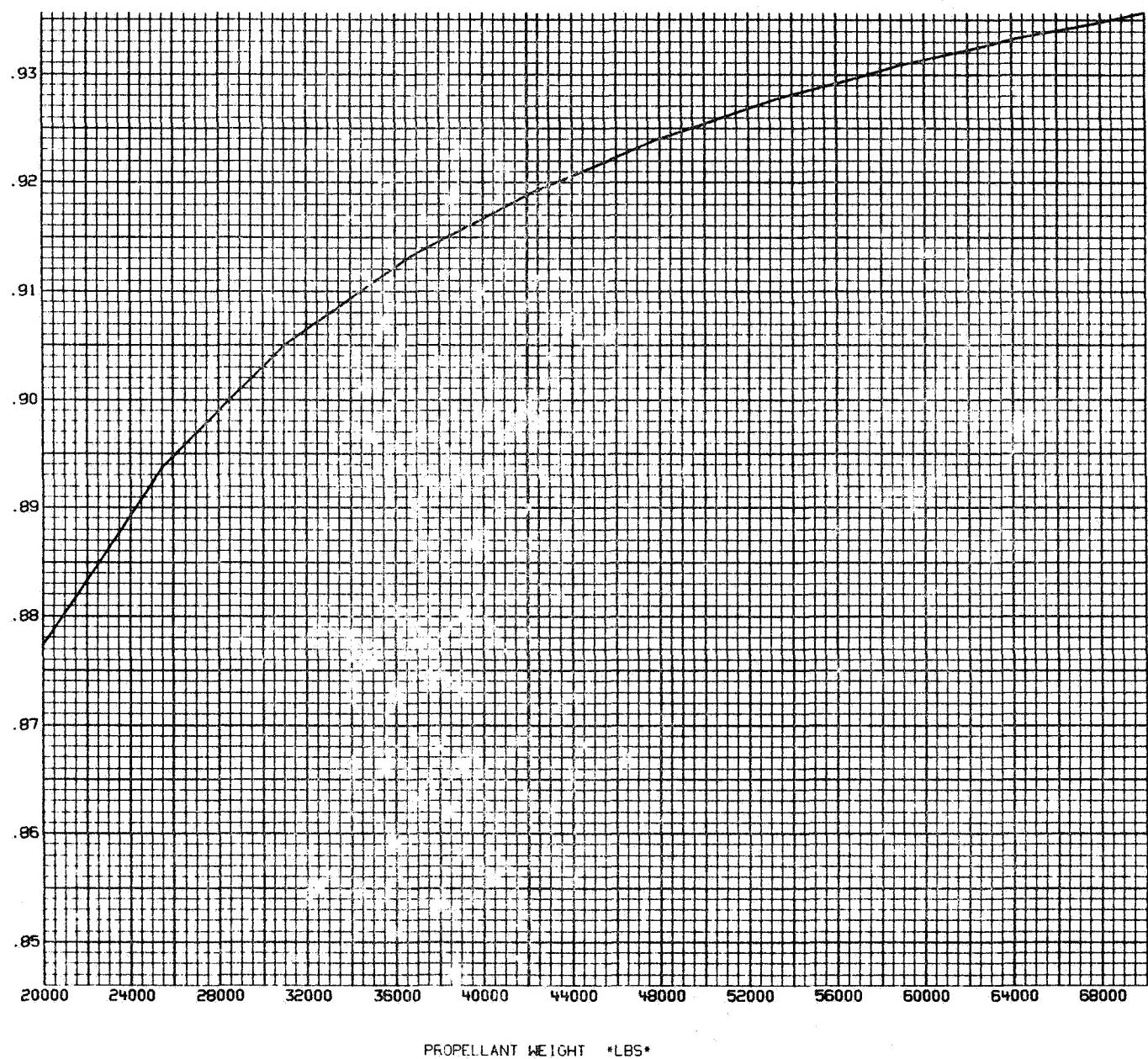


Figure 2-85

DROP TANK STRUCTURE

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460 SEC. SPECIFIC IMPULSE

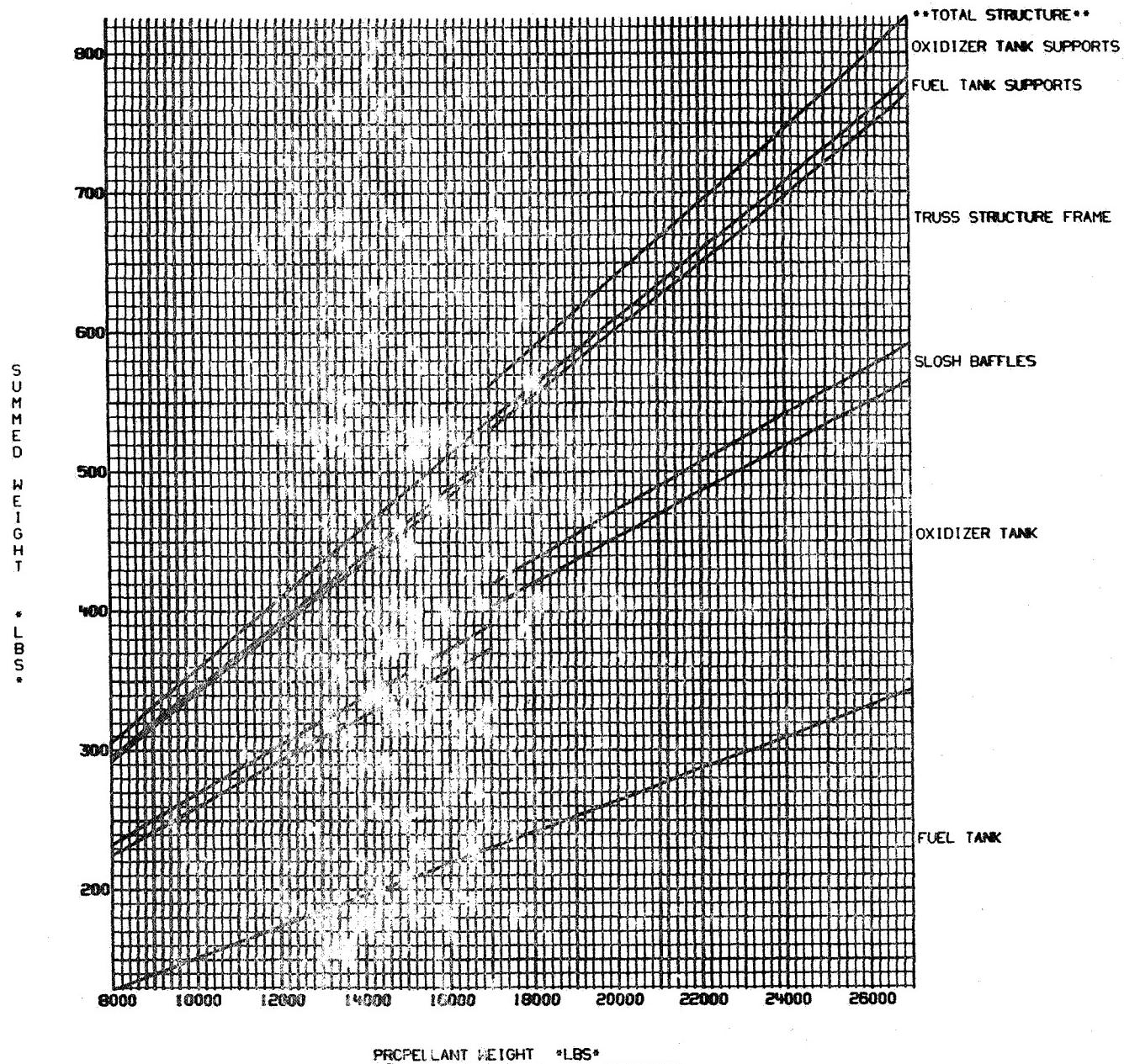


Figure 2-86

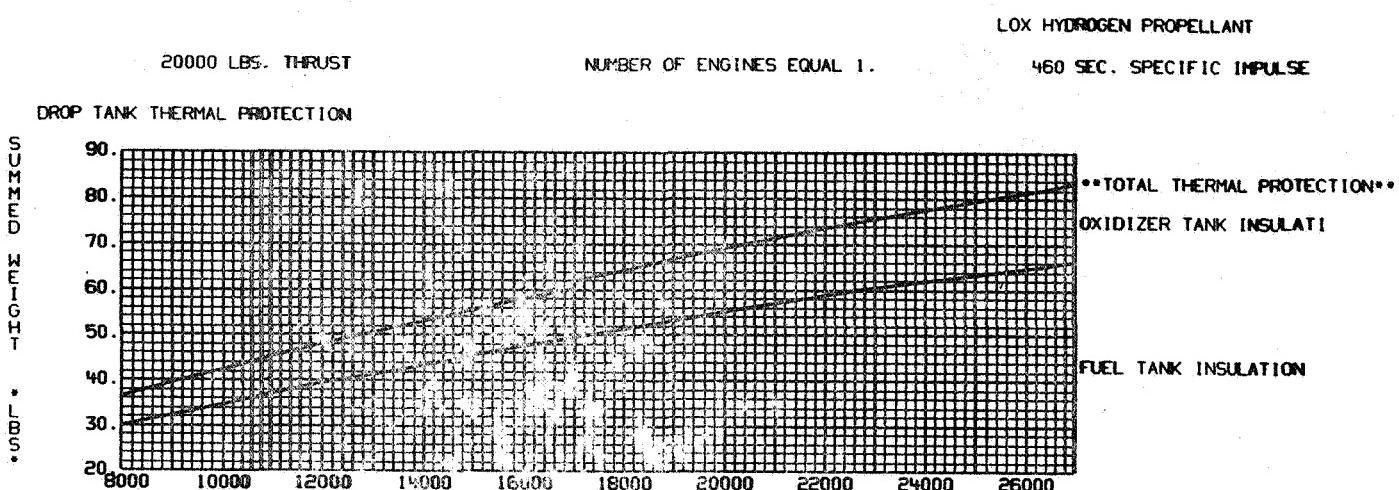


Figure 2-87

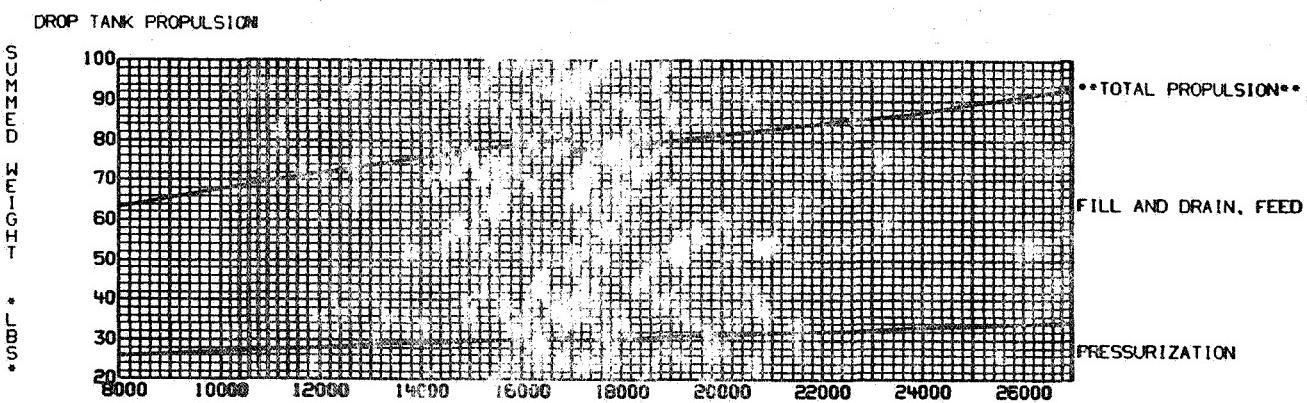


Figure 2-88

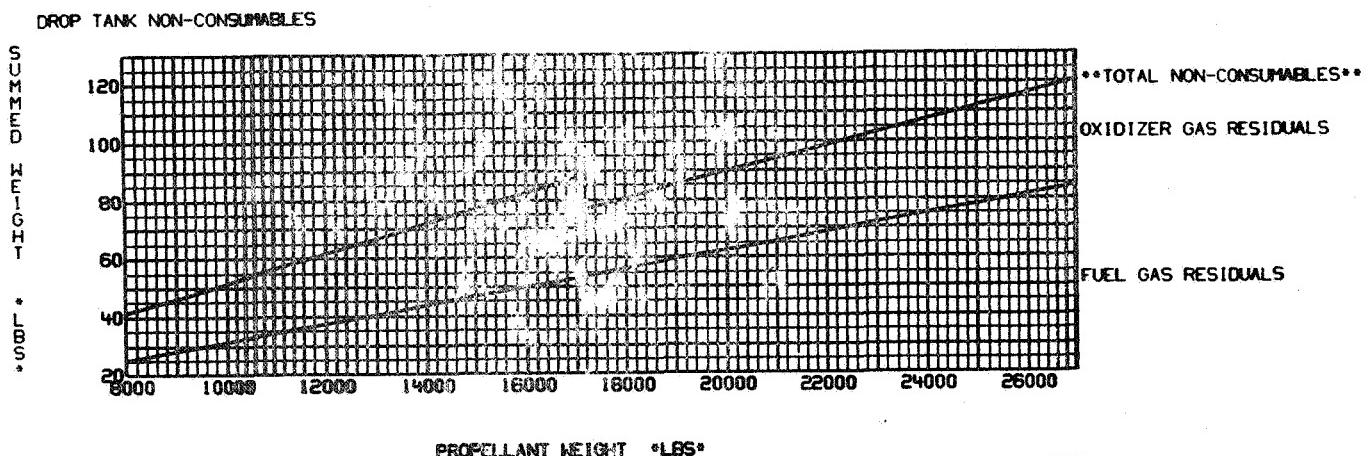


Figure 2-89

DROP TANK TOTAL SUBSYSTEMS

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460 SEC. SPECIFIC IMPULSE

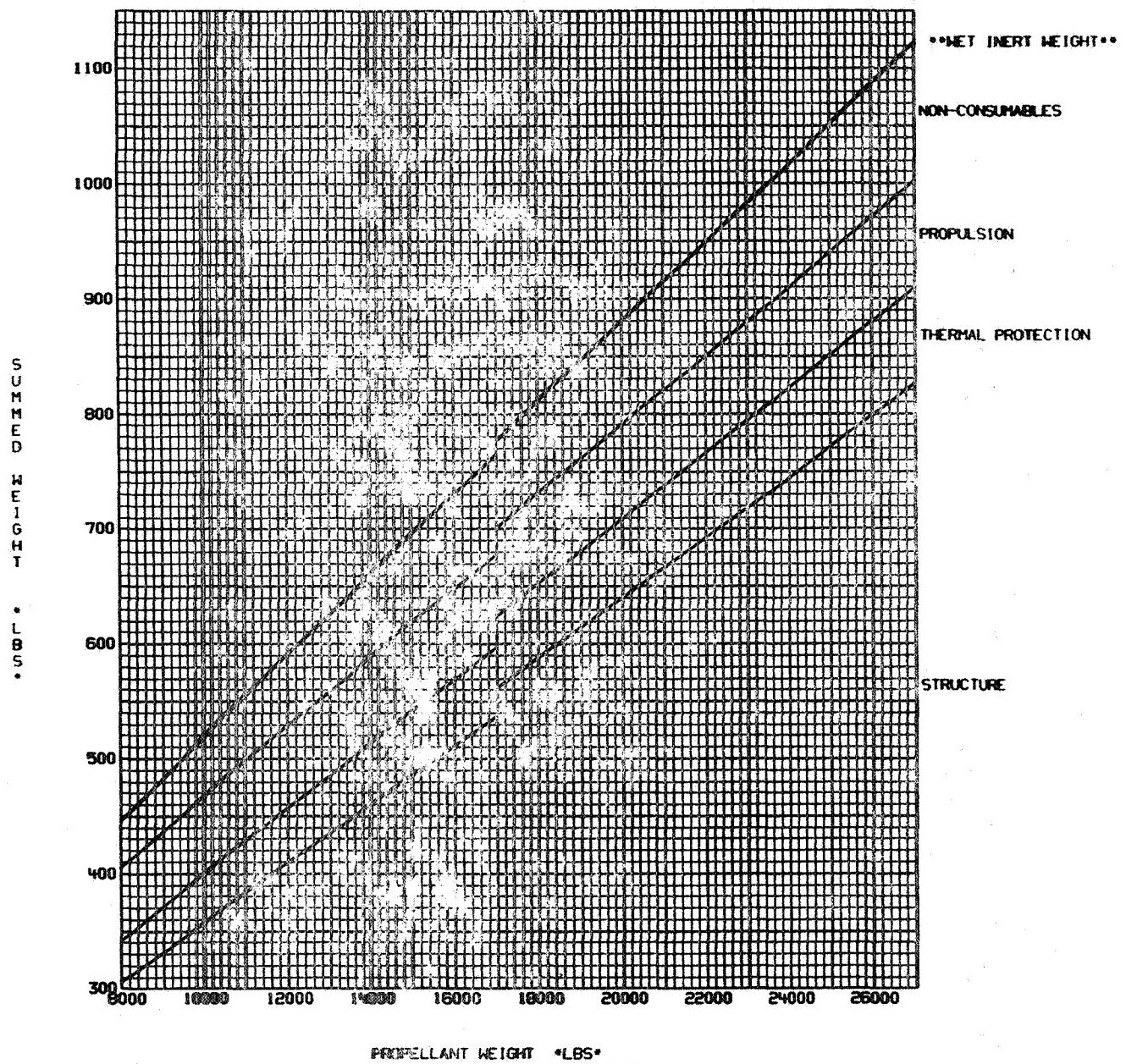


Figure 2-90

Chapter 3

PERFORMANCE DATA

This chapter presents detailed data on the performance characteristics and sensitivities associated with expendable orbit injection stages and reusable Space Tugs analyzed during the Space Tug Economic Analysis Study. The Tug concepts for which performance data are presented in this chapter are all point designs of primary interest in the study, namely the four candidate orbit injection stages (Agena, Large Tank Agena, D-1T Centaur, and Growth Tank Centaur), and single-stage ground-based reusable Tugs with LO_2/LH_2 , LF_2/LH_2 and FLOX/ CH_4 propellants. The reusable Tugs are generally sized to about 50,000 lb propellant loading, except that a smaller (36,300 lb) LO_2/LH_2 concept is included to show the performance variation with decreased stage size.

The performance data were generated automatically within the STAR computer program and directly plotted by the computer. The equations and methodology used to derive the performance data are presented in Part 1 of Volume II.

To assist the reader in locating any particular performance data in Chapter 3, a roadmap matrix of Tug concepts and performance data has been formatted; this matrix references specific figure numbers in the pages following. The matrix is presented as Table 3-1. Flight modes referenced for the reusable Tugs are as follows:

- Mode 1 - Delivery of a payload on the outbound leg of a roundtrip Tug flight and return with a payload of equal weight on the inbound leg
- Mode 2 - Retrieval, only, of a payload on a roundtrip Tug flight
- Mode 3 - Delivery, only, of a payload on a roundtrip Tug flight
- Mode 4 - Delivery of a payload on a one-way Tug flight

All of the orbit injection stages are flown in Mode 4.

Table 3-1. ROADMAP OF TUG PERFORMANCE DATA IN CHAPTER 3
(All References are to Figure Numbers)

	Orbit Injection Stages	Reusable LO ₂ /LH ₂ Tug (W _P = 50.2K)	Reusable LO ₂ /LH ₂ Tug (W _P = 36.3K)	Reusable LF ₂ /LH ₂ Tug (W _P = 47.8K)	Reusable FLOX/CH ₄ Tug (W _P = 52.0K)
Agena LT 'D'-IT GT	Agena Centaur Centaur	Mode 1 Mode 2 Mode 3 Mode 4	Mode 1 Mode 2 Mode 3 Mode 4	Mode 1 Mode 2 Mode 3 Mode 4	Mode 1 Mode 2 Mode 3 Mode 4
Payload Capability vs On-Orbit Velocity	3-1 3-8 3-15 3-22	3-29 3-36 3-45 3-52	3-59 3-68 3-75 3-82	3-89 3-98 3-105 3-112	3-119 3-125 3-135 3-142
Partial Derivative of Payload Capability with Respect to Tug I, sp	3-2 3-9 3-16 3-23	3-30 3-39 3-46 3-53	3-60 3-69 3-76 3-83	3-90 3-99 3-106 3-113	3-120 3-129 3-136 3-143
Partial Derivative of Payload Capability with Respect to Tug Inert Weight	3-3 3-10 3-17 3-24	3-31 3-40 3-47 3-54	3-61 3-70 3-77 3-84	3-91 3-100 3-107 3-114	3-121 3-130 3-137 3-144
Partial Derivative of Payload Capability with Respect to Outbound Velocity	3-4 3-11 3-18 3-25	3-32 N/A 3-45 3-55	3-62 N/A 3-78 3-85	3-92 N/A 3-108 3-115	3-122 N/A 3-136 3-145
Partial Derivative of Payload Capability with Respect to Inbound Velocity	N/A N/A N/A N/A	3-33 3-41 N/A N/A	3-63 3-71 N/A N/A	3-93 3-101 N/A N/A	3-123 3-131 N/A N/A
Partial Derivative of Payload Capability with Respect to Tug Propellant Weight	3-5 3-12 3-19 3-26	3-34 3-42 3-49 3-56	3-64 3-72 3-79 3-86	3-94 3-102 3-109 3-116	3-124 3-132 3-139 3-146
Partial Derivative of Payload Capability with Respect to Tug Ignition Weight	3-6 3-13 3-20 3-27	3-35 3-43 3-50 3-57	3-65 3-73 3-80 3-87	3-95 3-103 3-110 3-117	3-125 3-133 3-140 3-147
Partial Derivative of Payload Capability with Respect to Ratio of Outbound to Total Payload	N/A N/A N/A N/A	3-36 N/A N/A N/A	3-66 N/A N/A N/A	3-96 N/A N/A N/A	3-126 N/A N/A N/A
Propellant Offloading vs On-Orbit Velocity	3-7 3-14 3-21 3-28	3-37 3-44 3-51 3-58	3-67 3-74 3-81 3-88	3-97 3-104 3-111 3-118	3-127 3-134 3-141 3-146

**STANDARD
AGENA**

PAYLOAD DELIVERED

13386 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

■ = EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

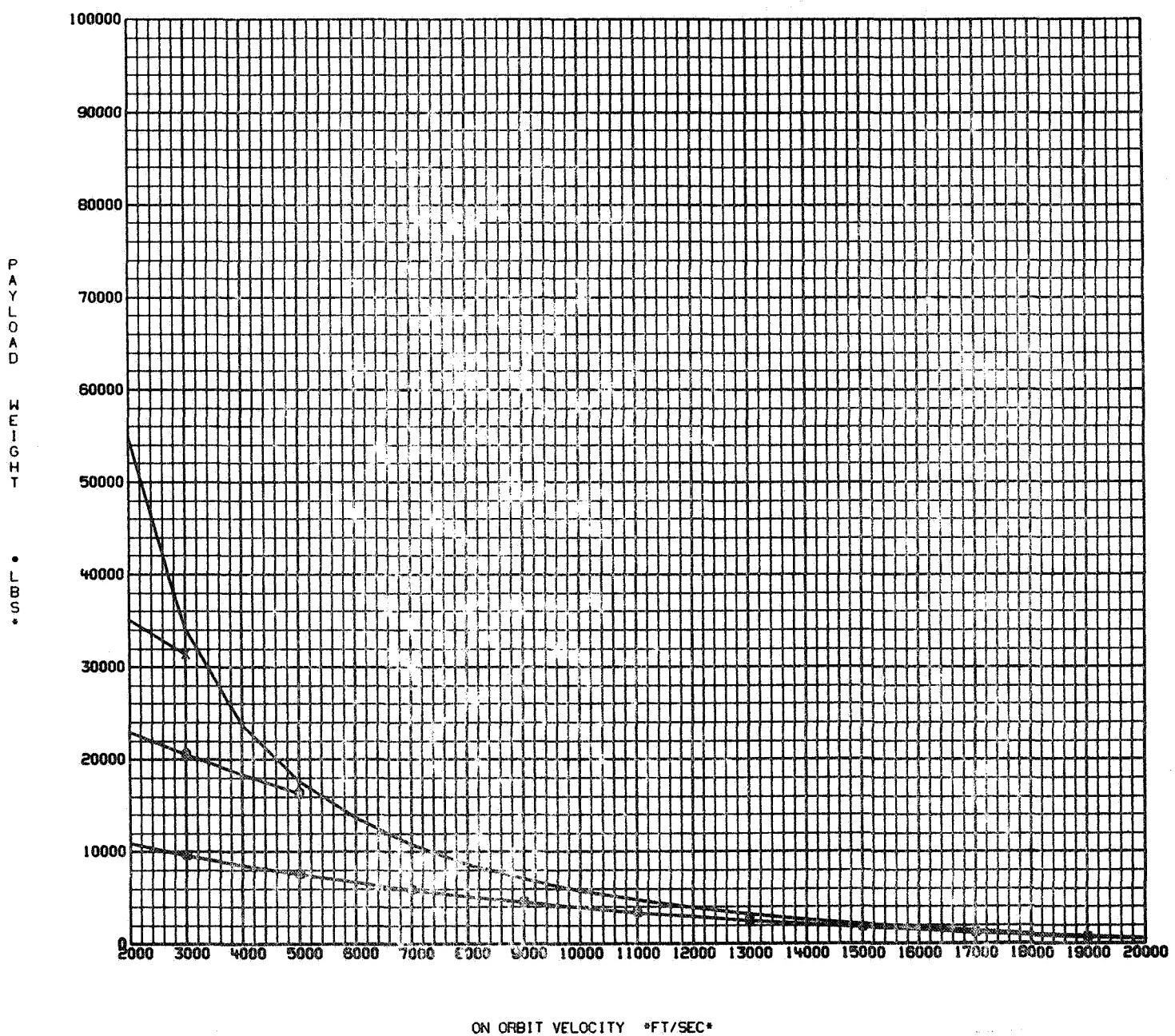
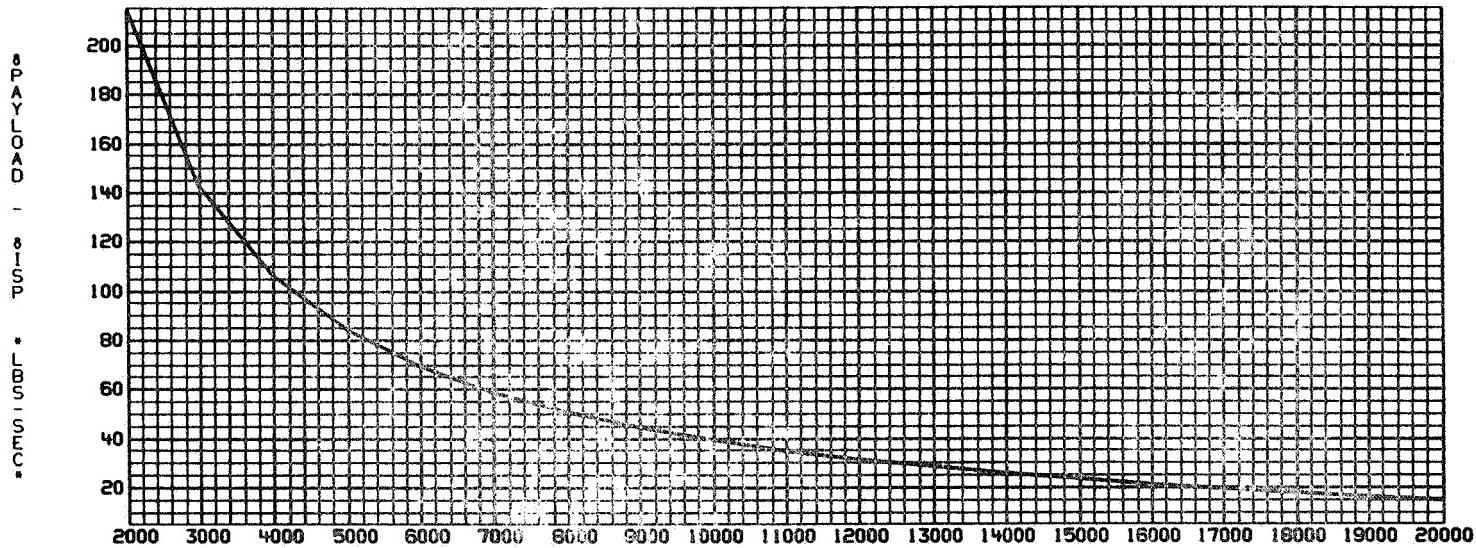


Figure 3-1

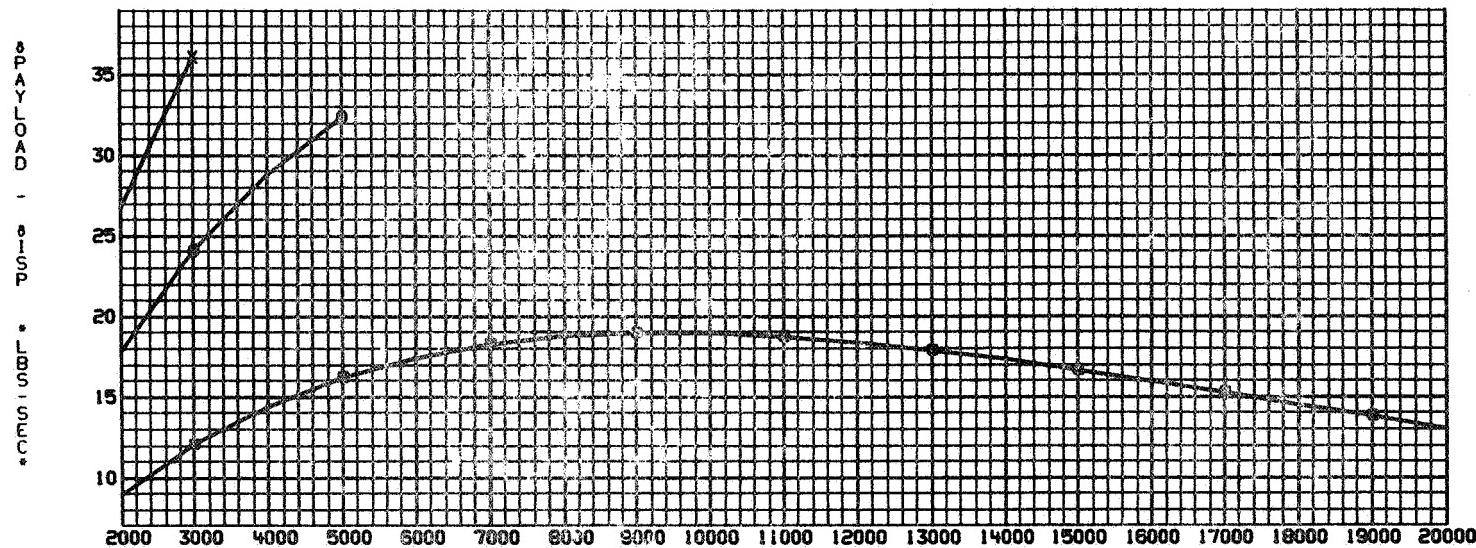
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ▨ = FIXED IGNITION 65000 LBS.



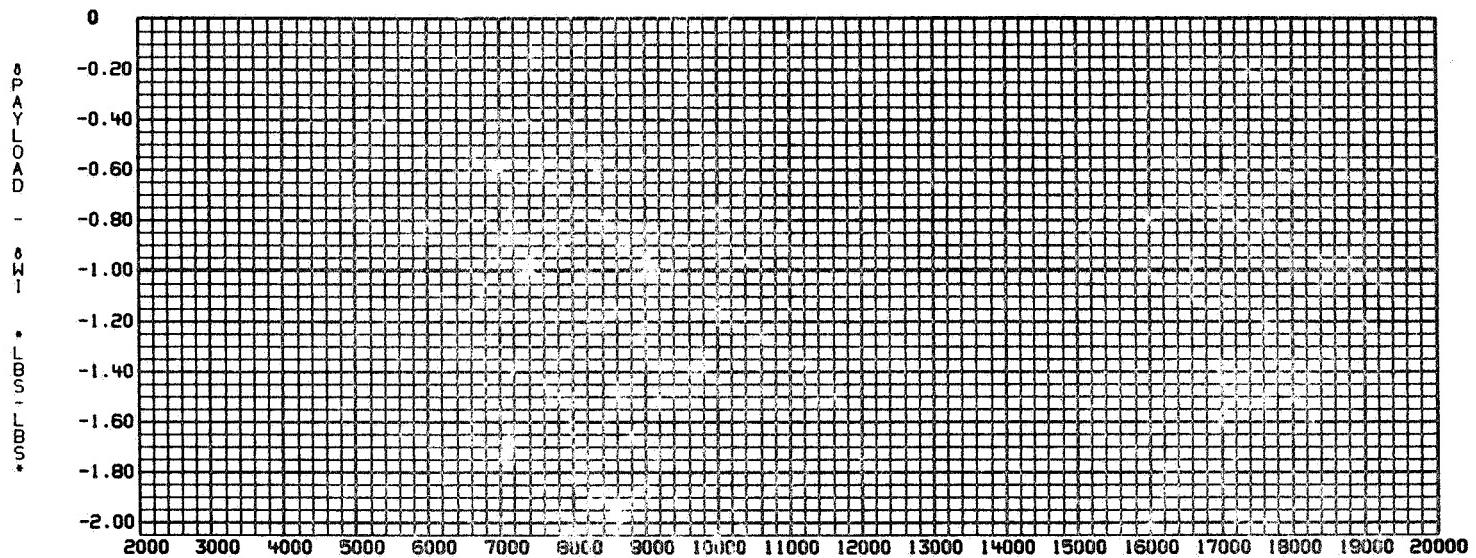
ON ORBIT VELOCITY *FT/SEC*

Figure 3-2

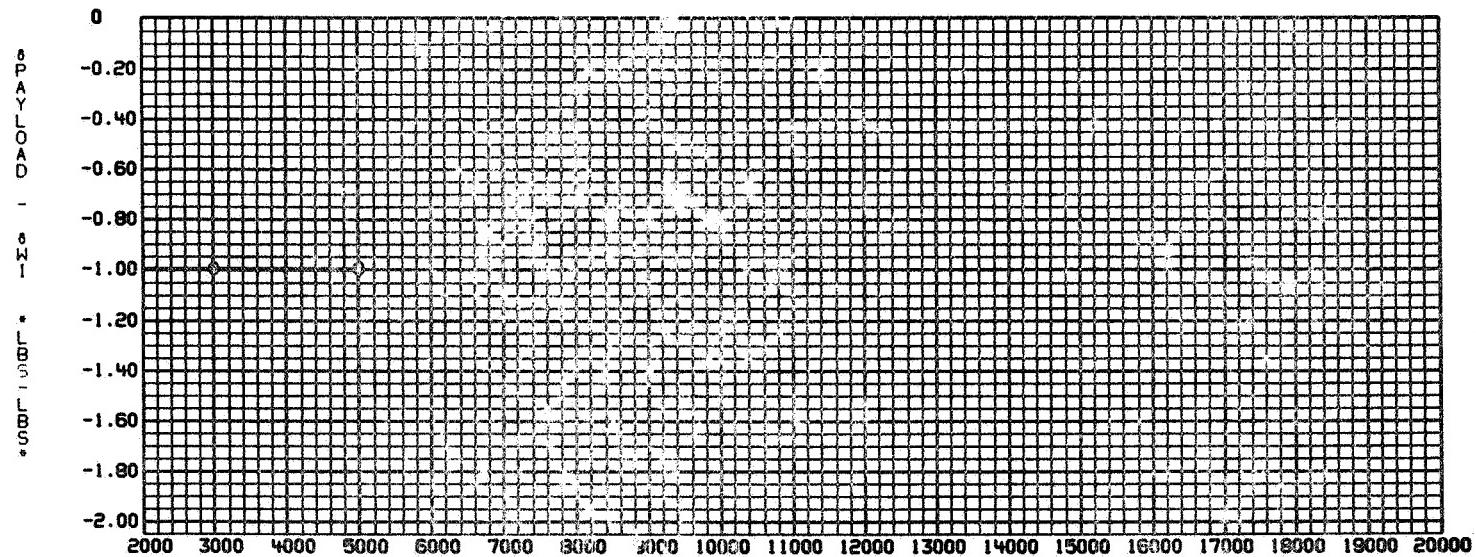
PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



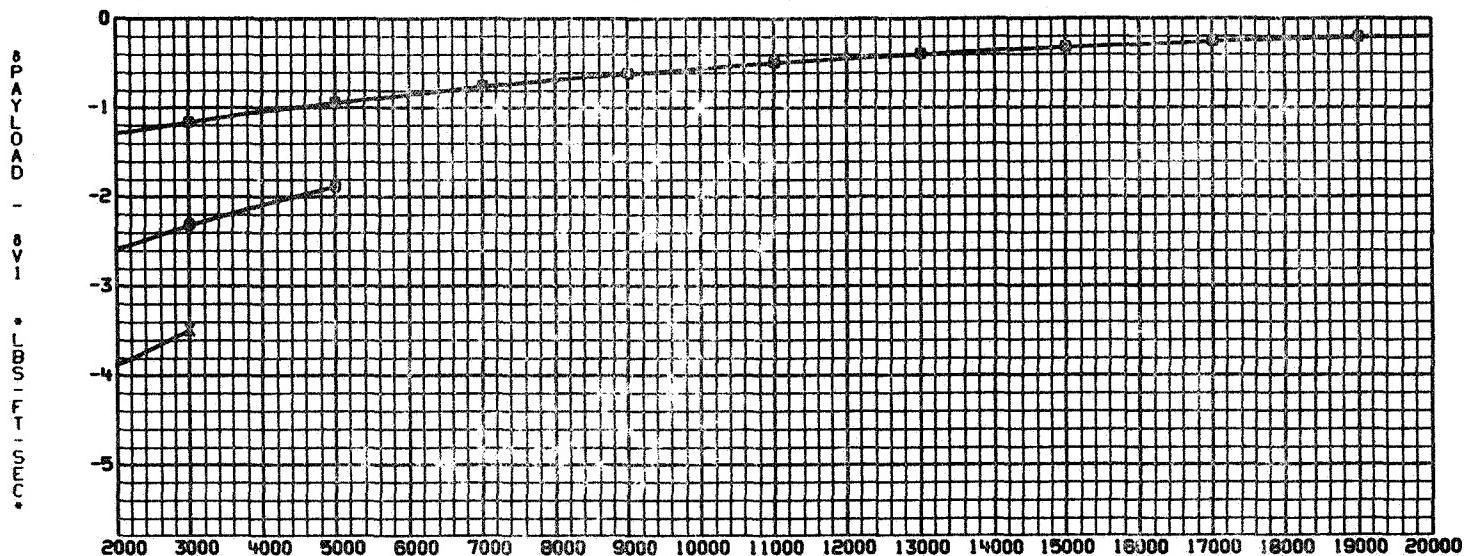
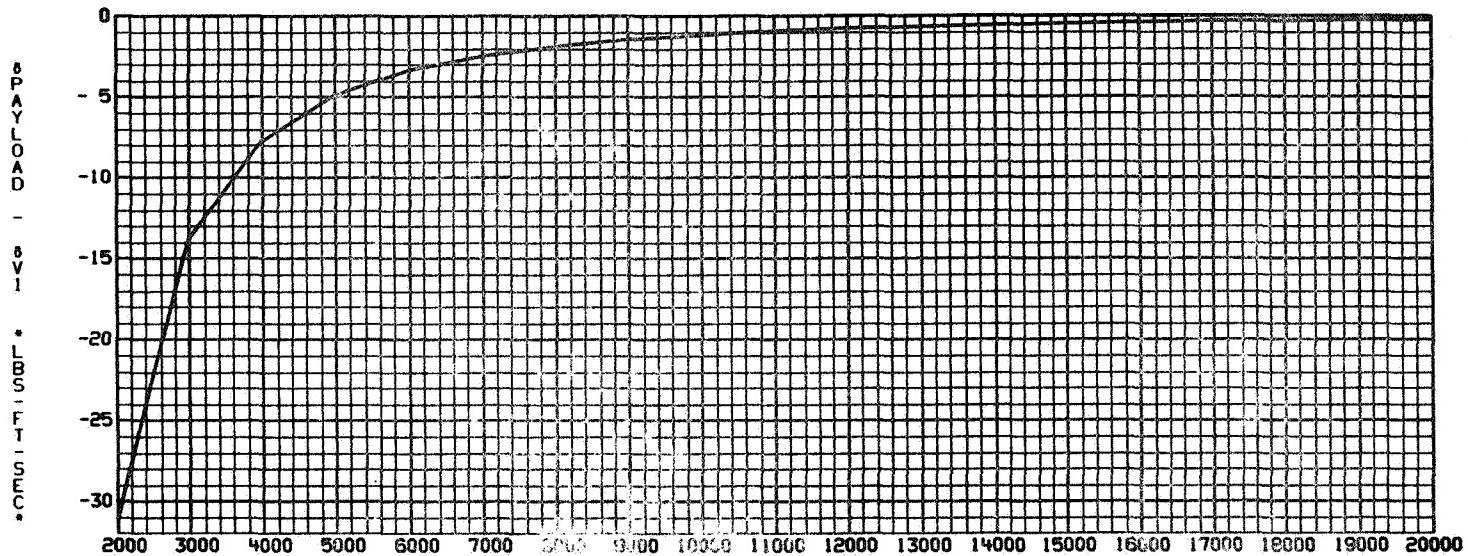
ON ORBIT VELOCITY *FT/SEC*

Figure 3-3

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-4

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT

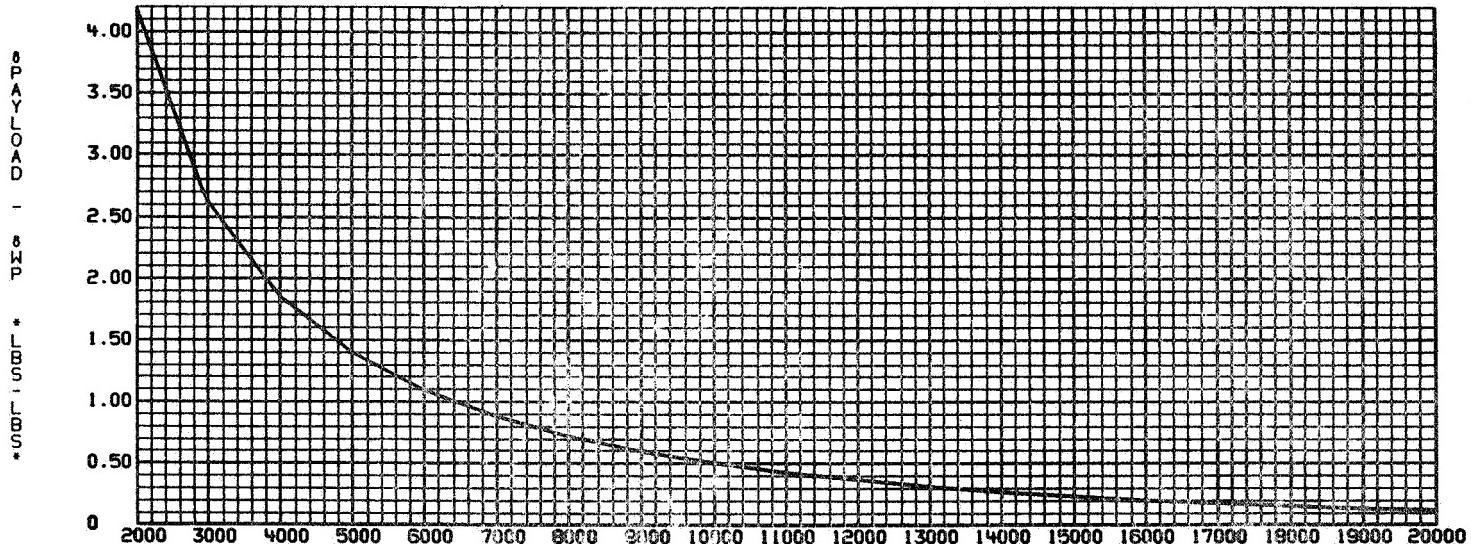
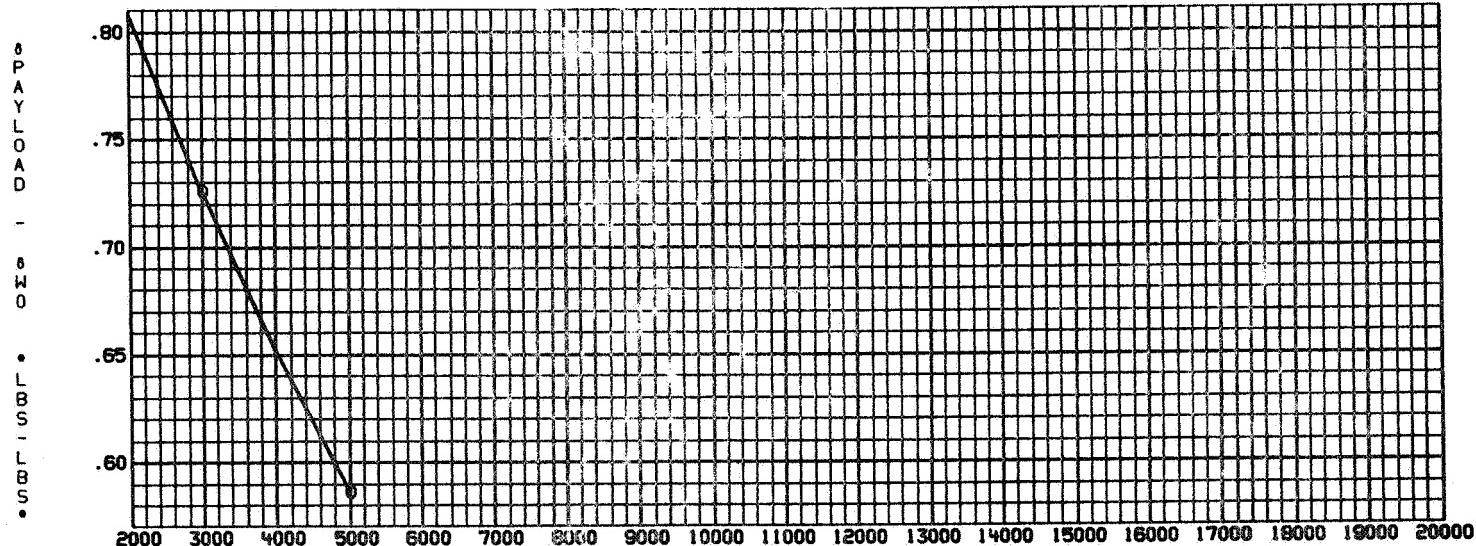


Figure 3-5

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-6

3-7

PAYLOAD DELIVERED

0 = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

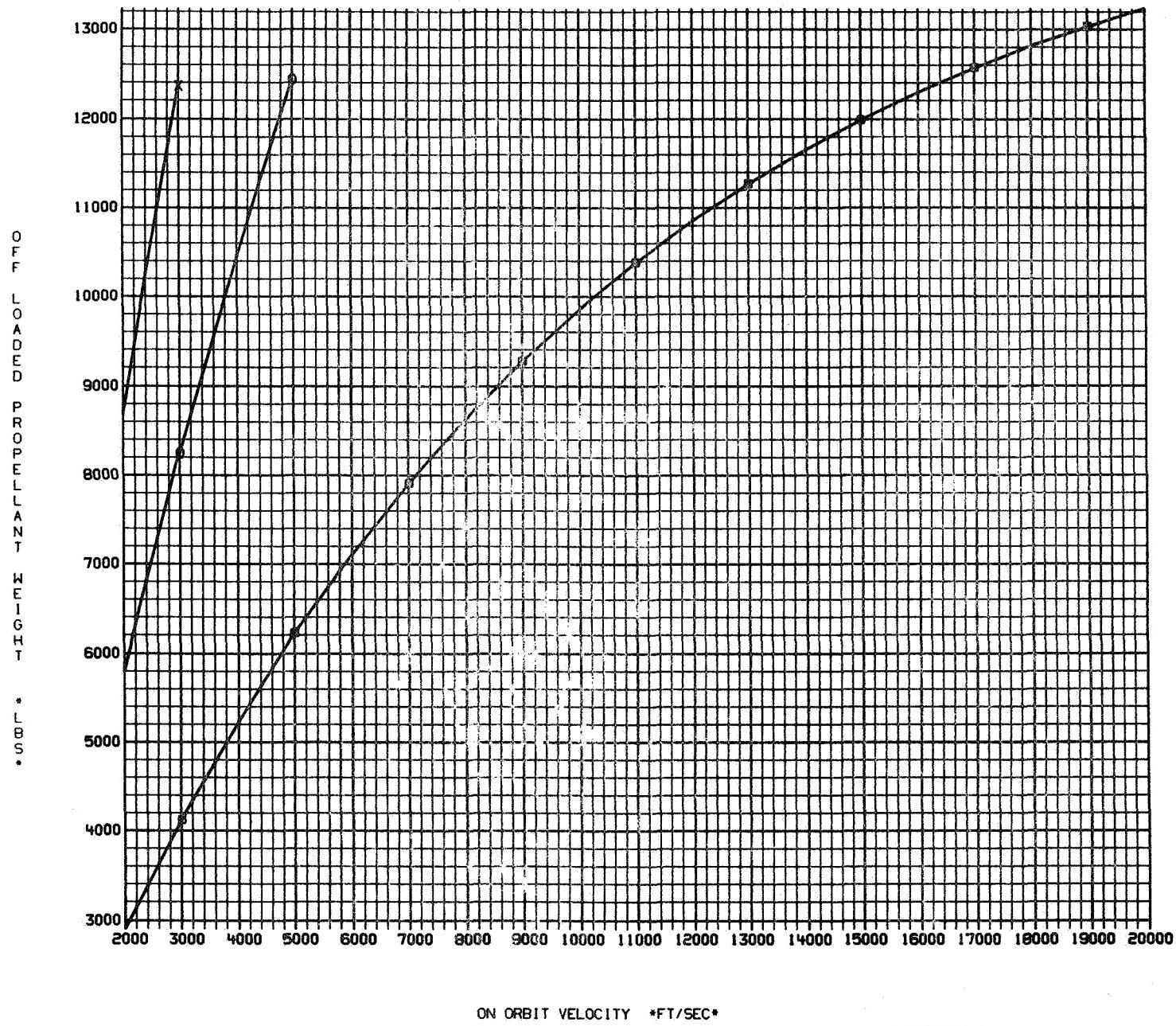


Figure 3-7

LARGE TANK AGENA

$W_p = 50,730 \text{ LB}$

PAYLOAD DELIVERED

- = FIXED PROPELLANT 50730 LBS.
- = FIXED IGNITION 45000 LBS.

50730 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 55000 LBS.
X = FIXED IGNITION 65000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 75000 LBS.

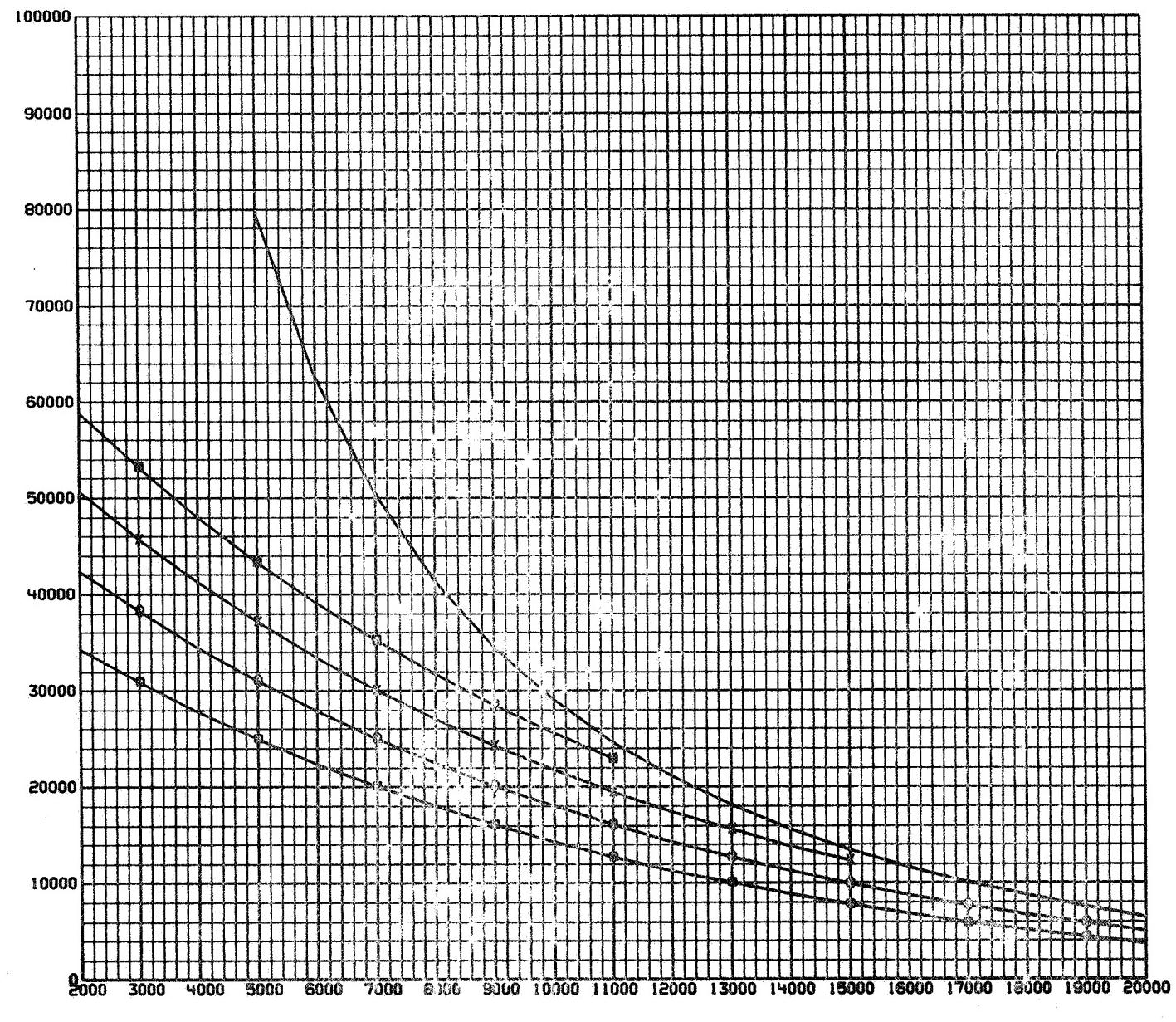


Figure 3-8

PAYLOAD DELIVERED
50730 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

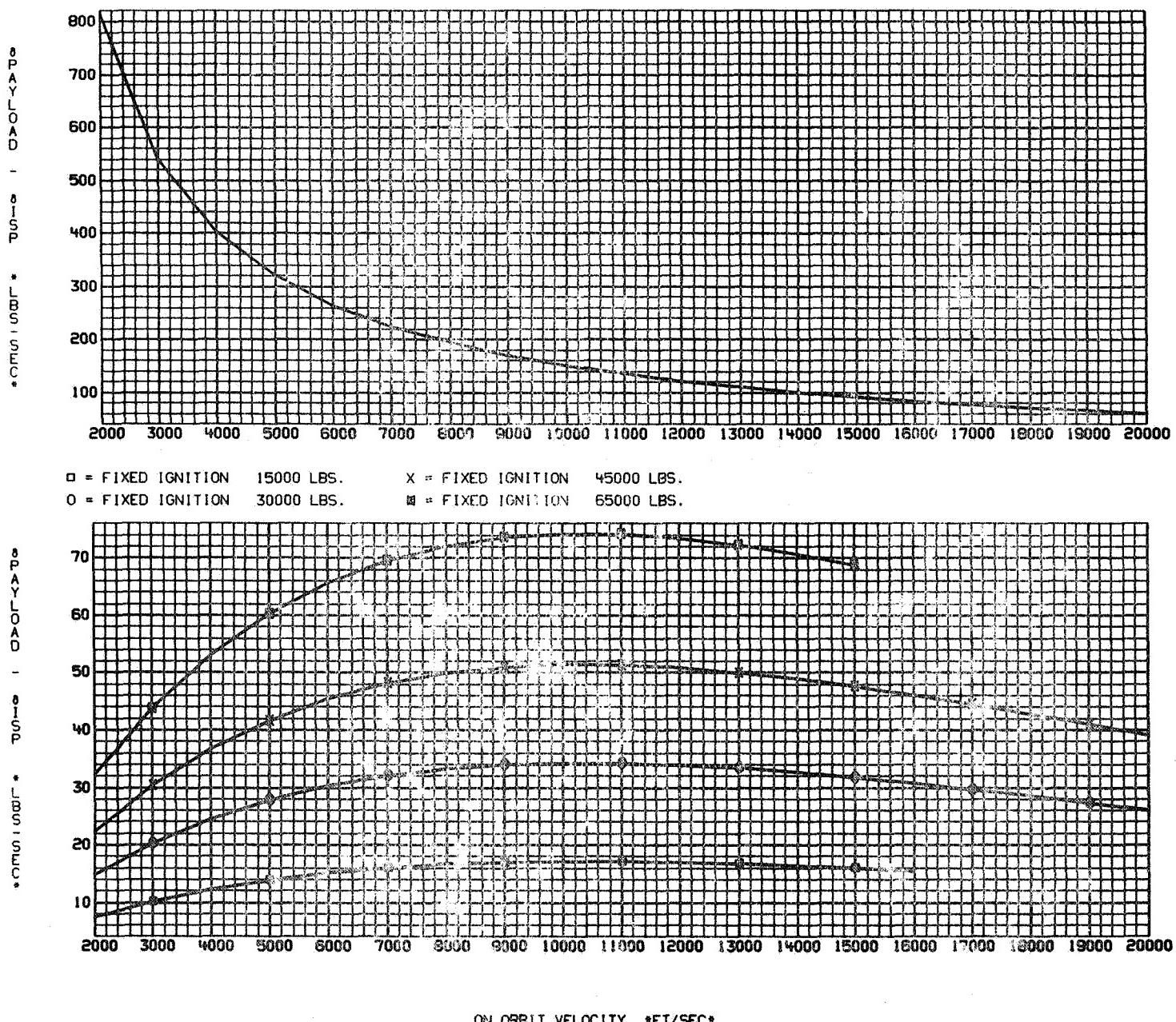
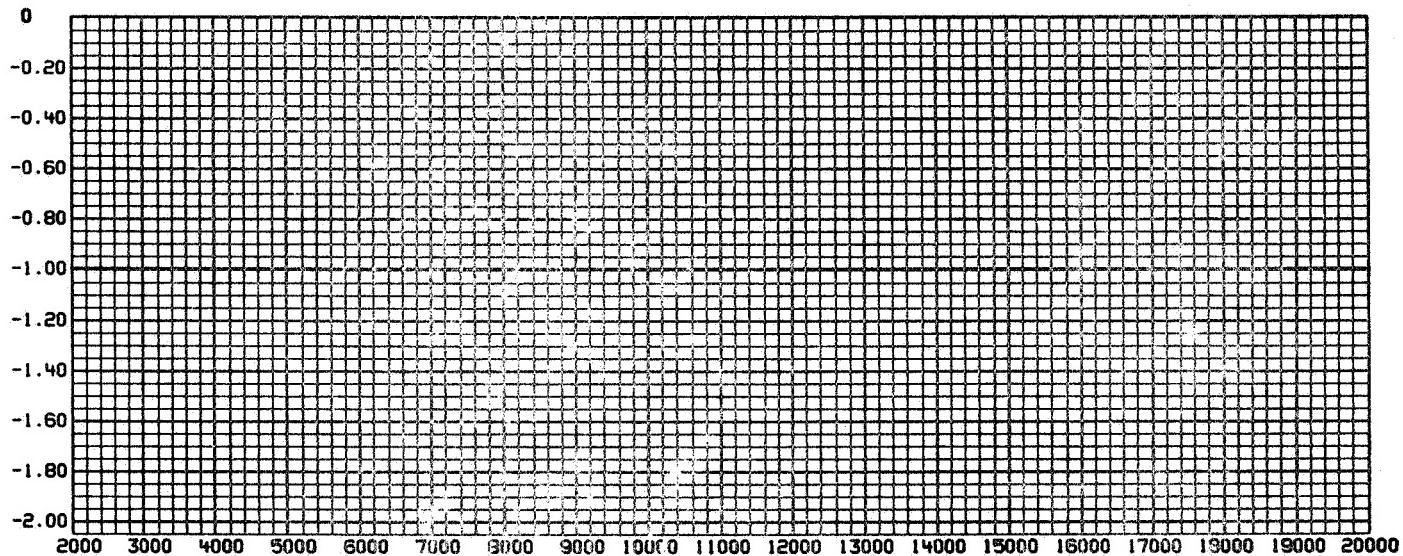


Figure 3-9

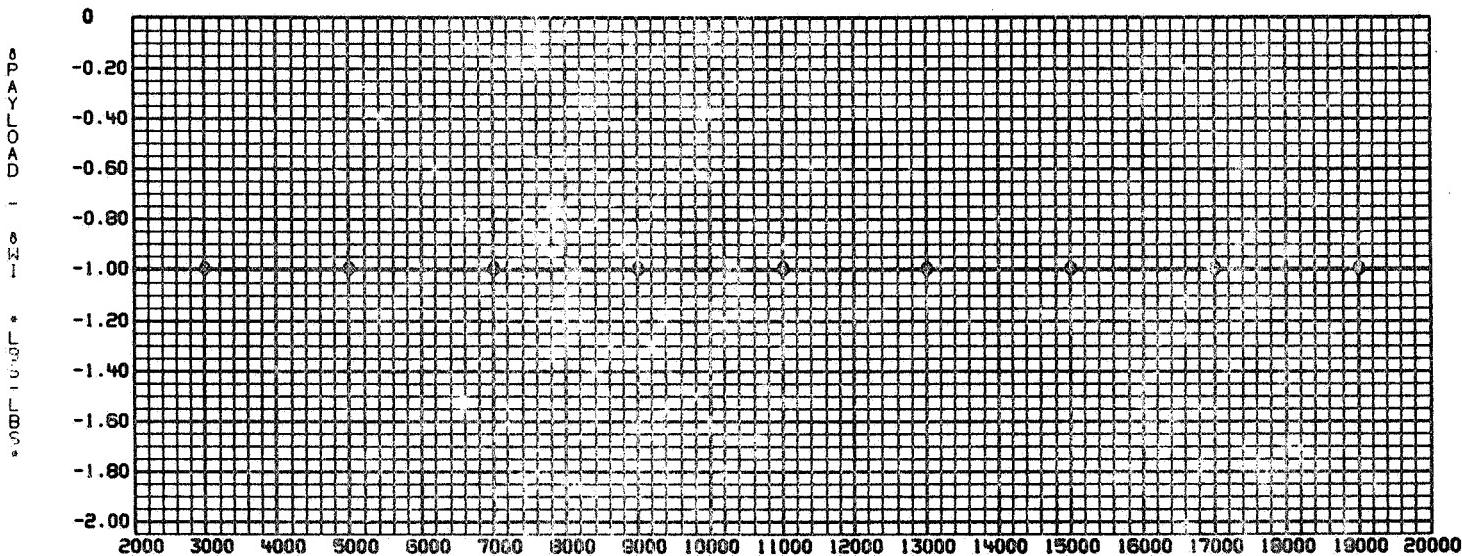
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



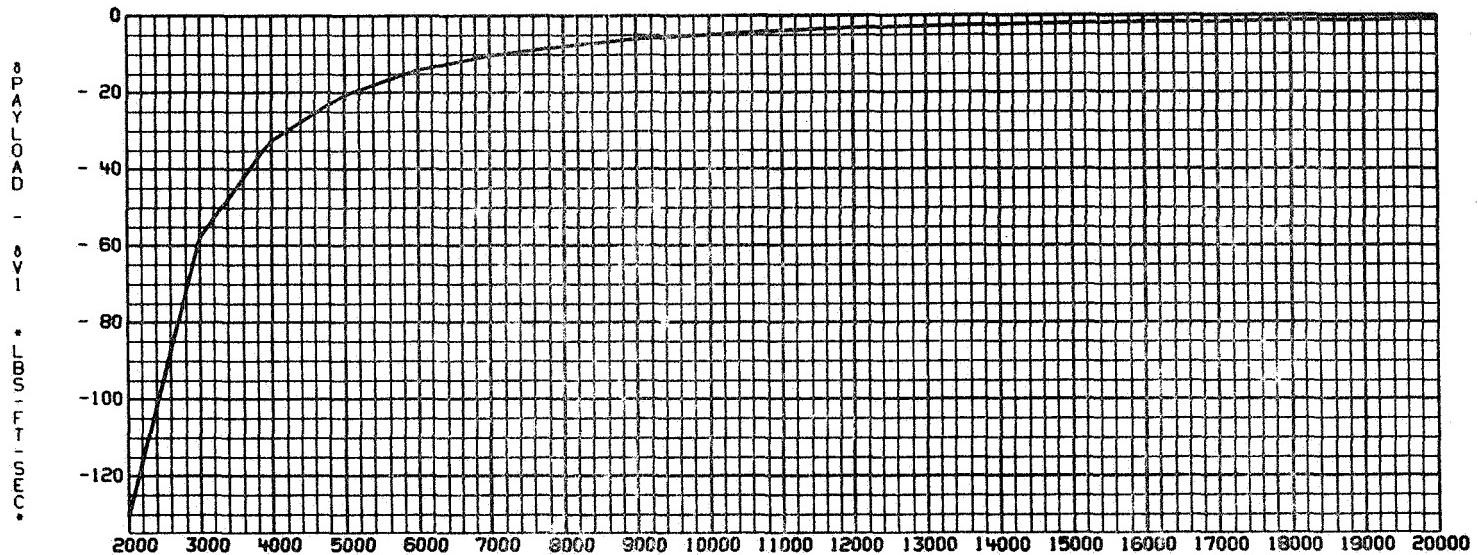
ON ORBIT VELOCITY *FT/SEC*

Figure 3-10

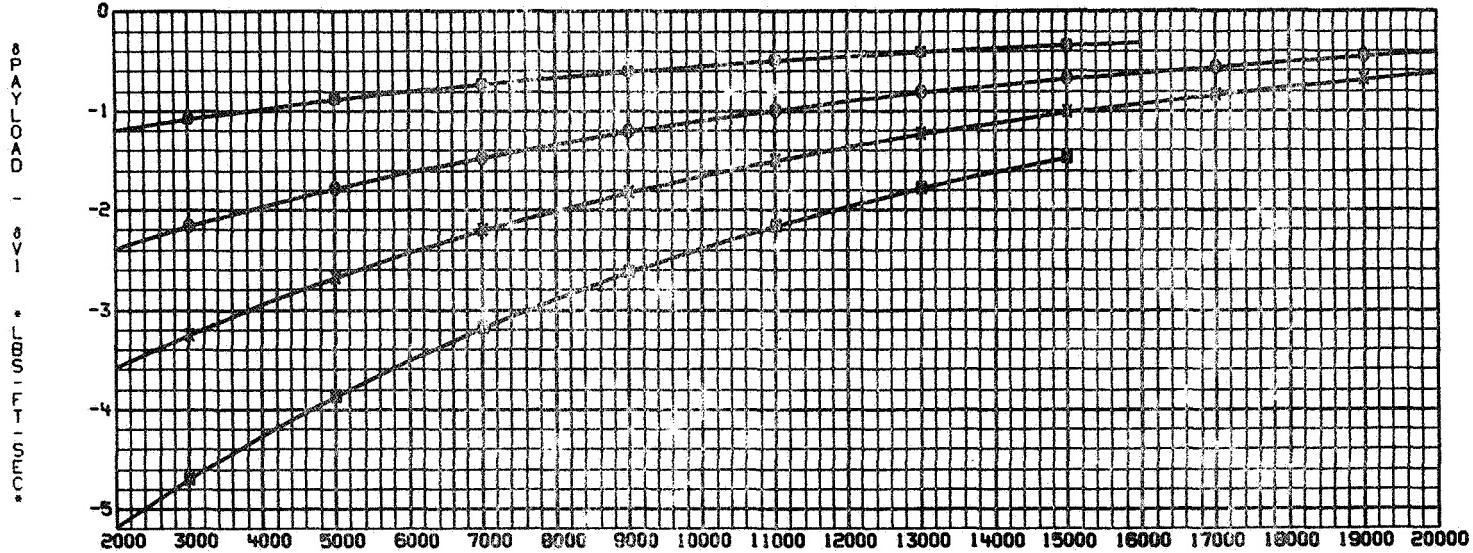
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT



\square = FIXED IGNITION 15000 LBS. x = FIXED IGNITION 45000 LBS.
 \circ = FIXED IGNITION 30000 LBS. \blacksquare = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-11

3-12

PAYLOAD DELIVERED
50730 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

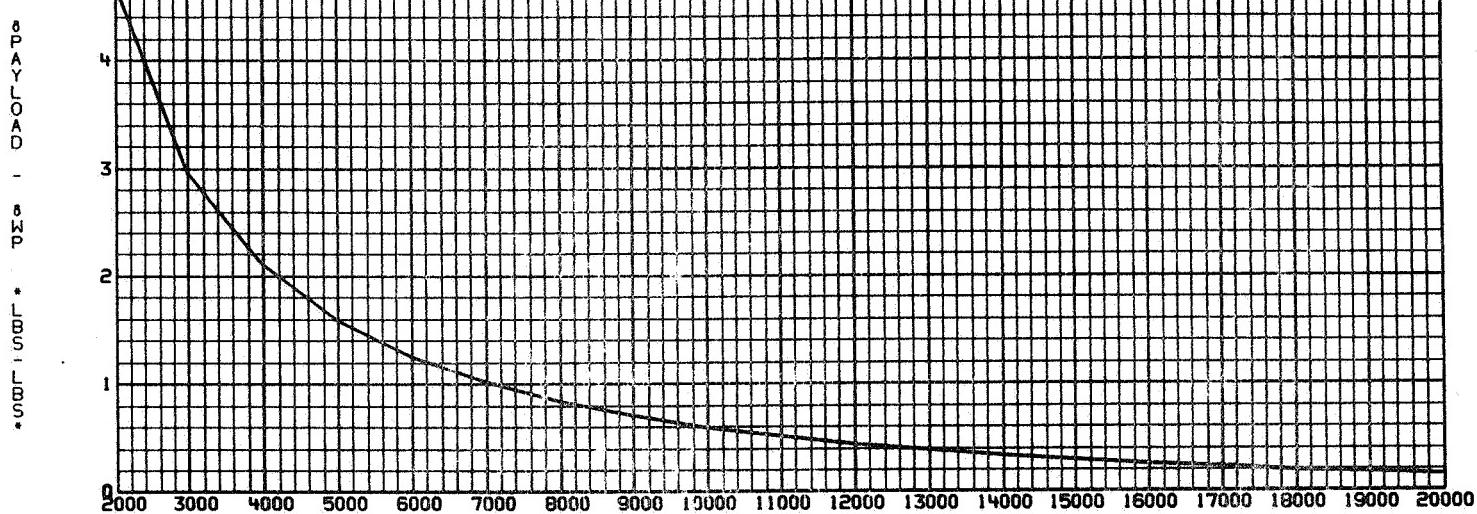
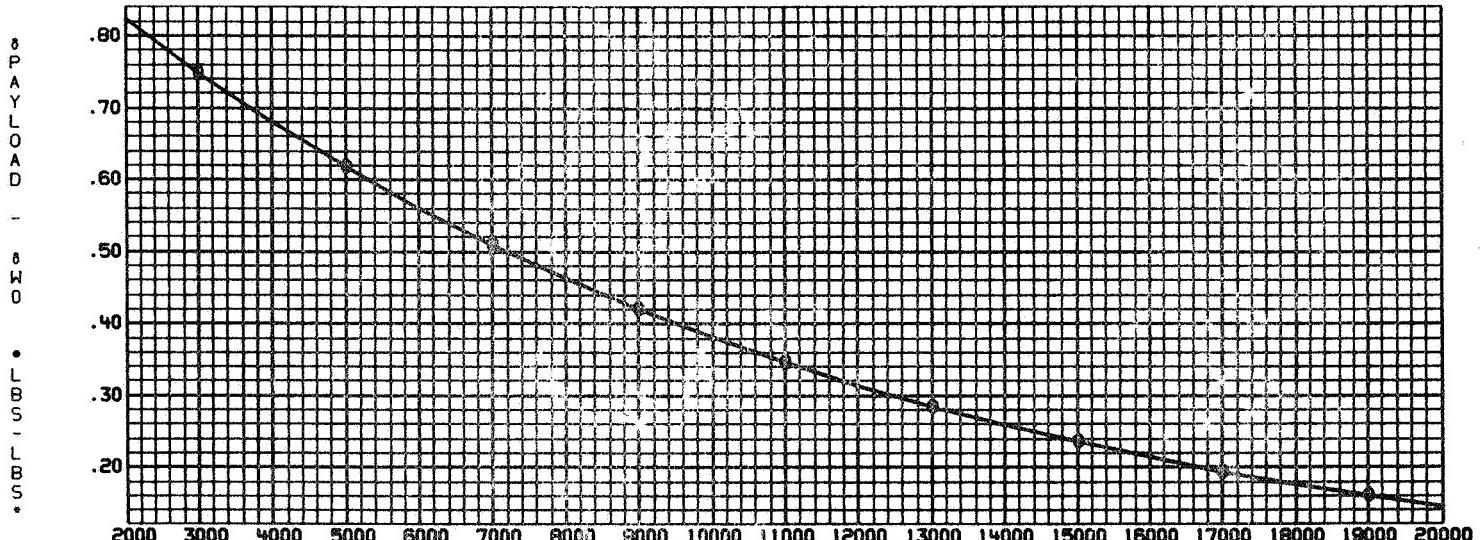


Figure 3-12

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-13

3-13

PAYLOAD DELIVERED

FIXED IGNITION WEIGHTS
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

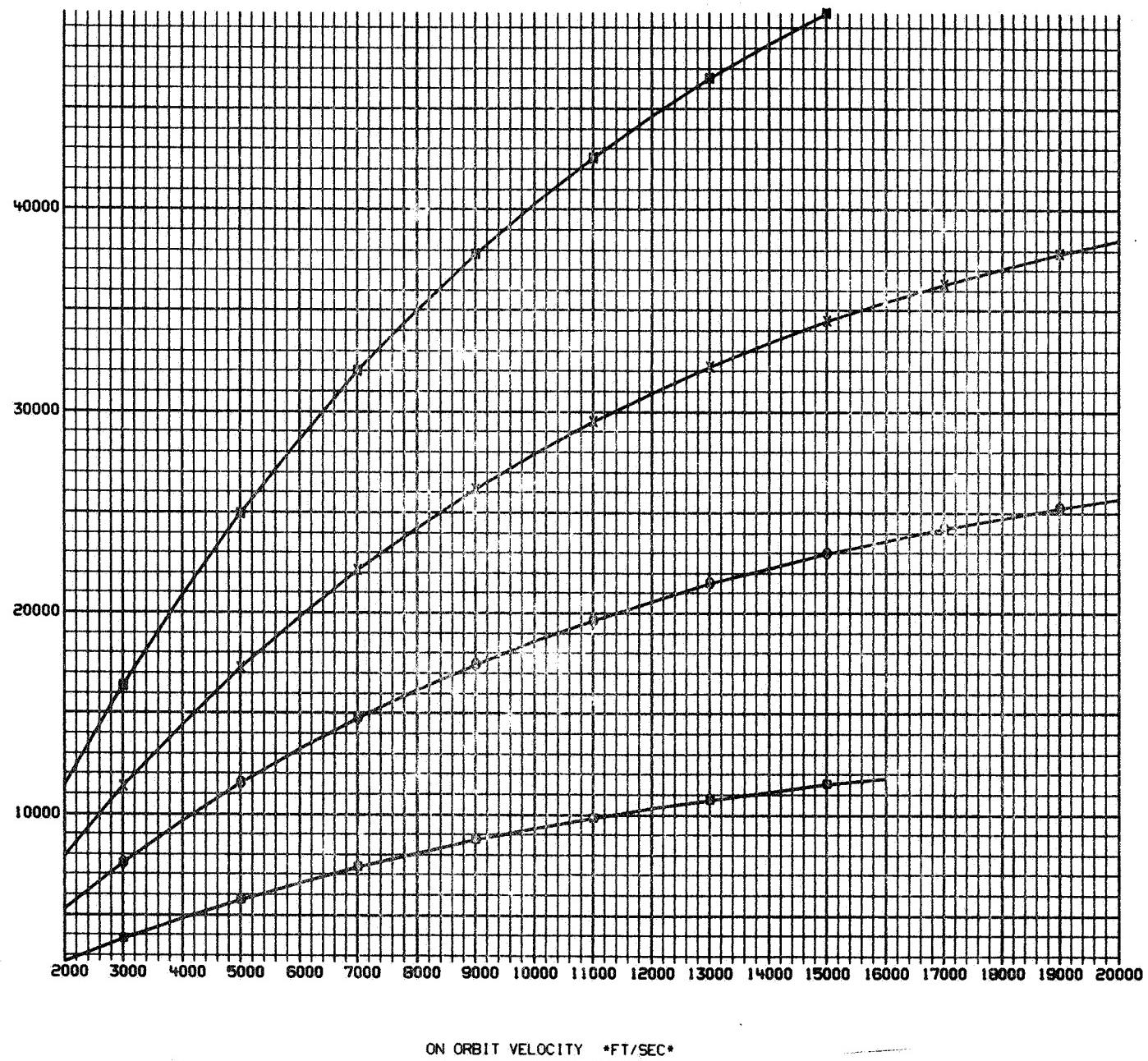


Figure 3-14

D-1T CENTAUR

PAYOUT DELIVERED 30000 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE TUG AND P/L
 = FIXED PROPELLANT 30000 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
 = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

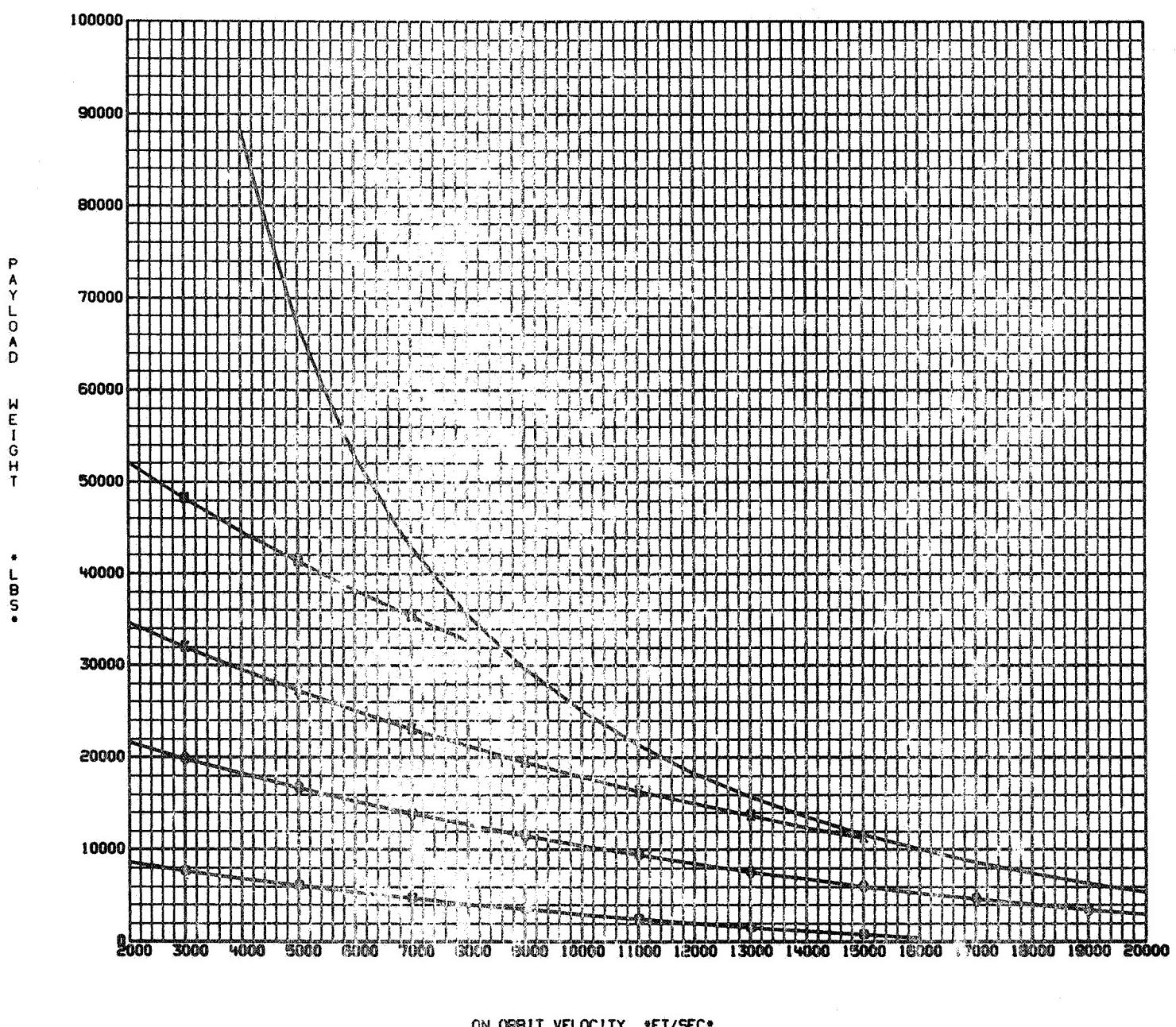
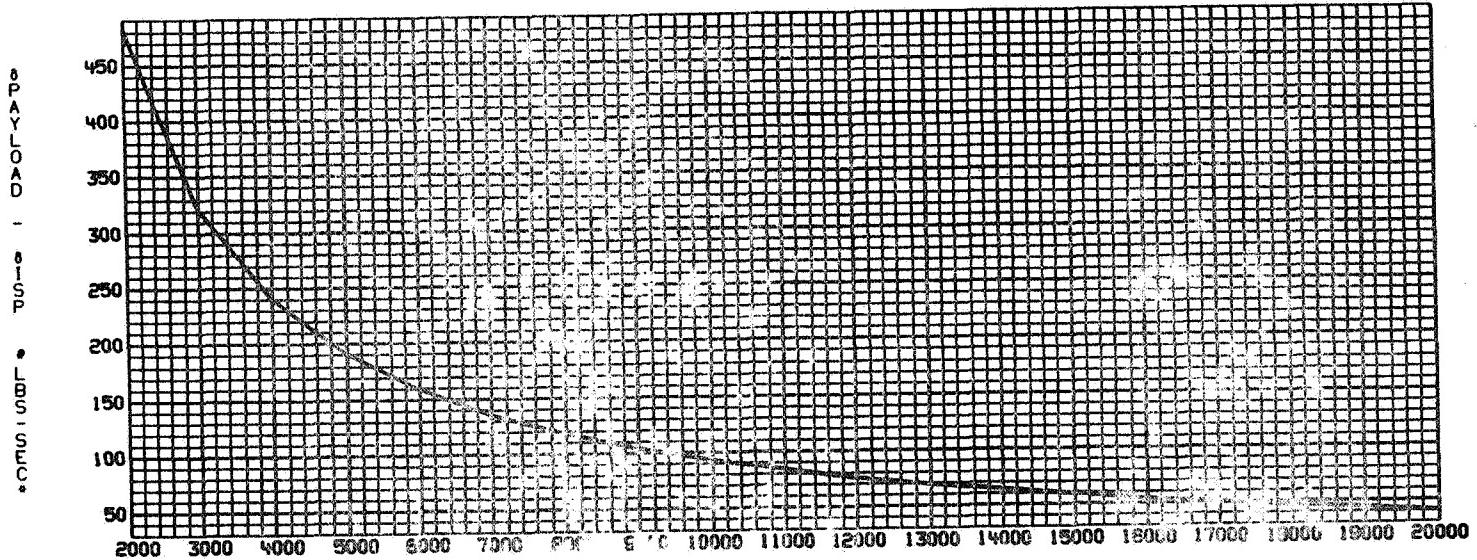


Figure 3-15

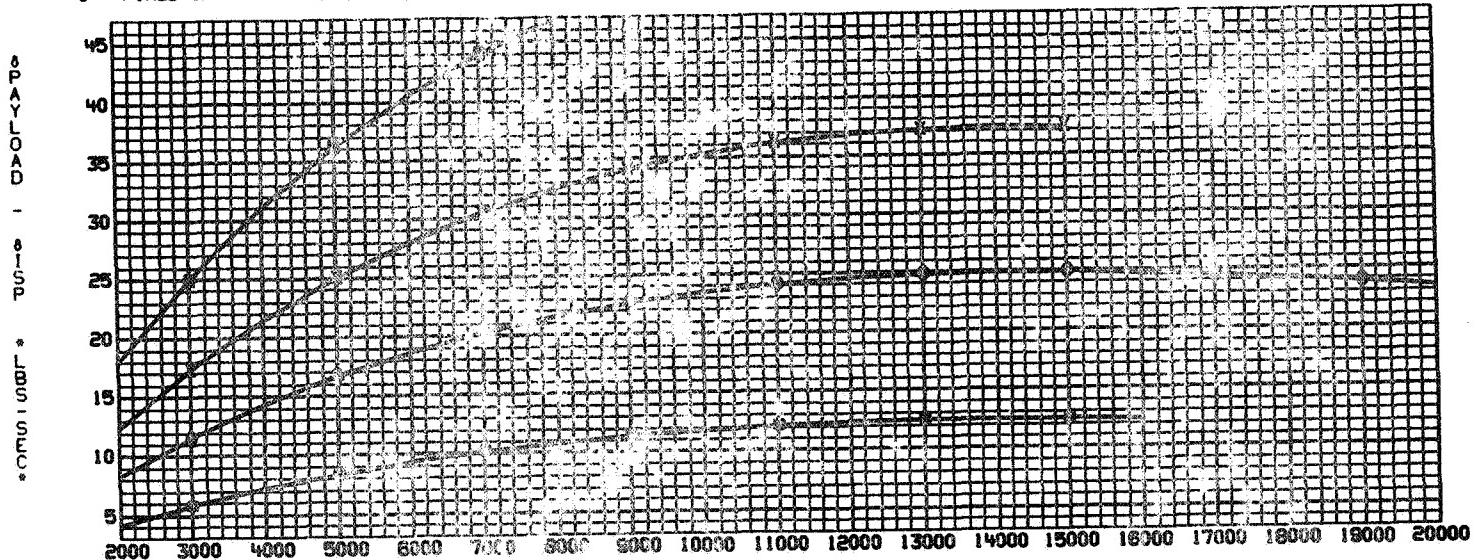
PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT



○ = FIXED IGNITION 15000 LBS. × = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. △ = FIXED IGNITION 65000 LBS.



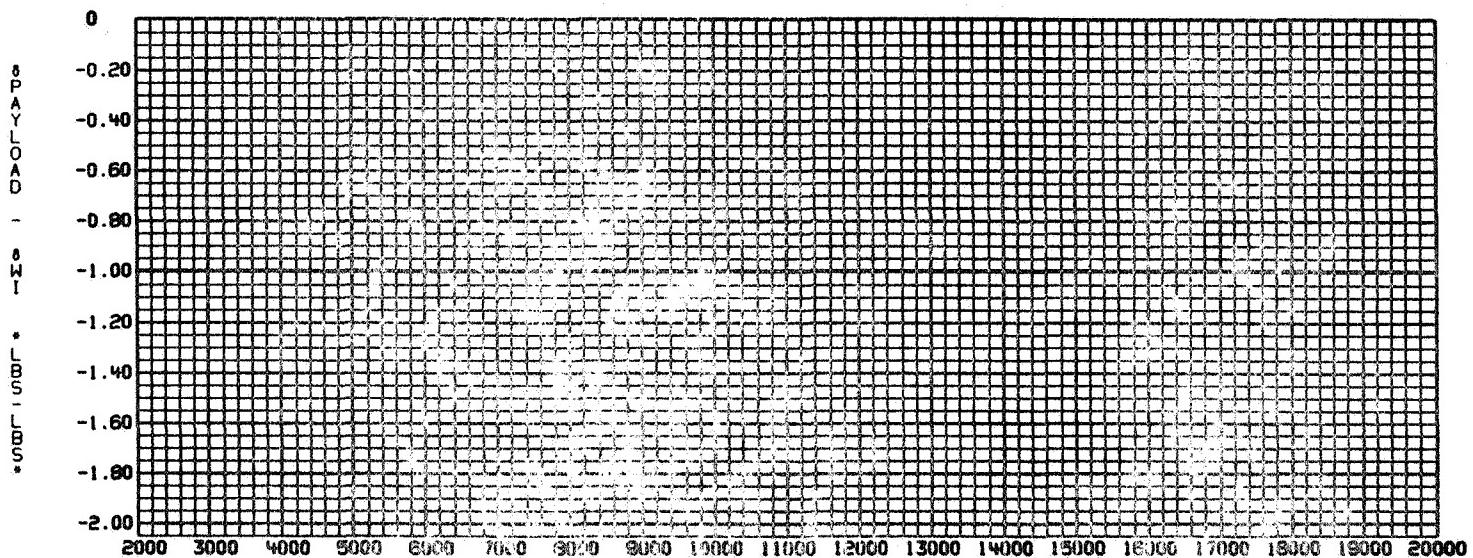
ON ORBIT VELOCITY *FT/SEC*

Figure 3-16

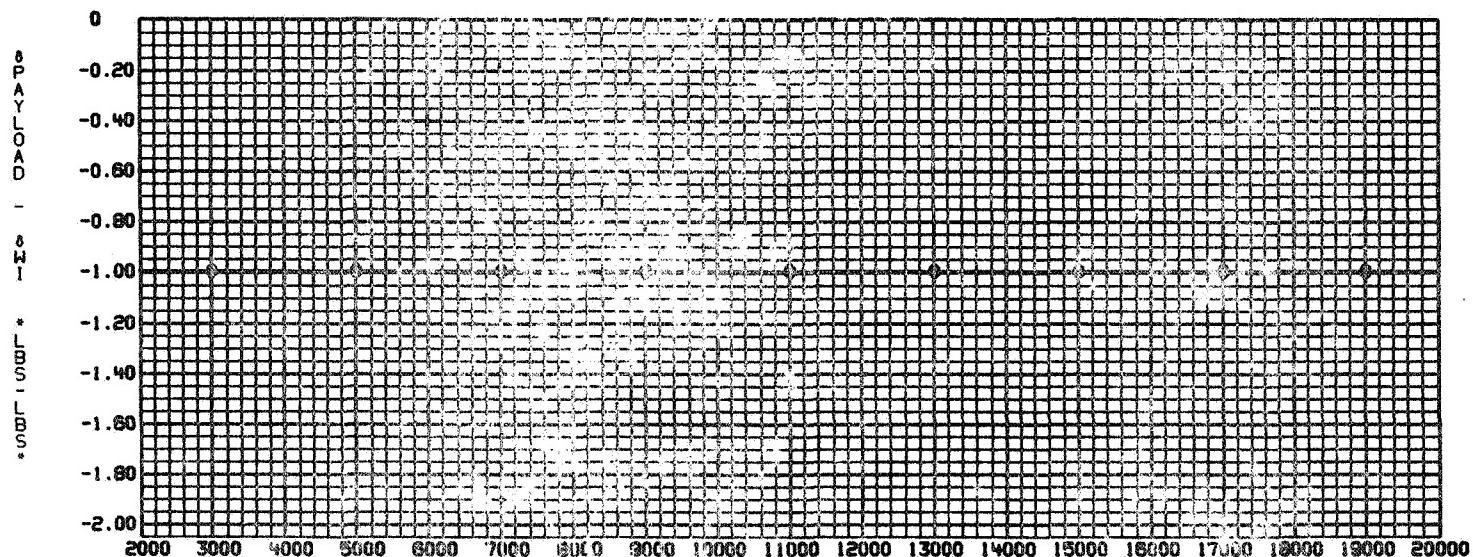
PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-17

PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT

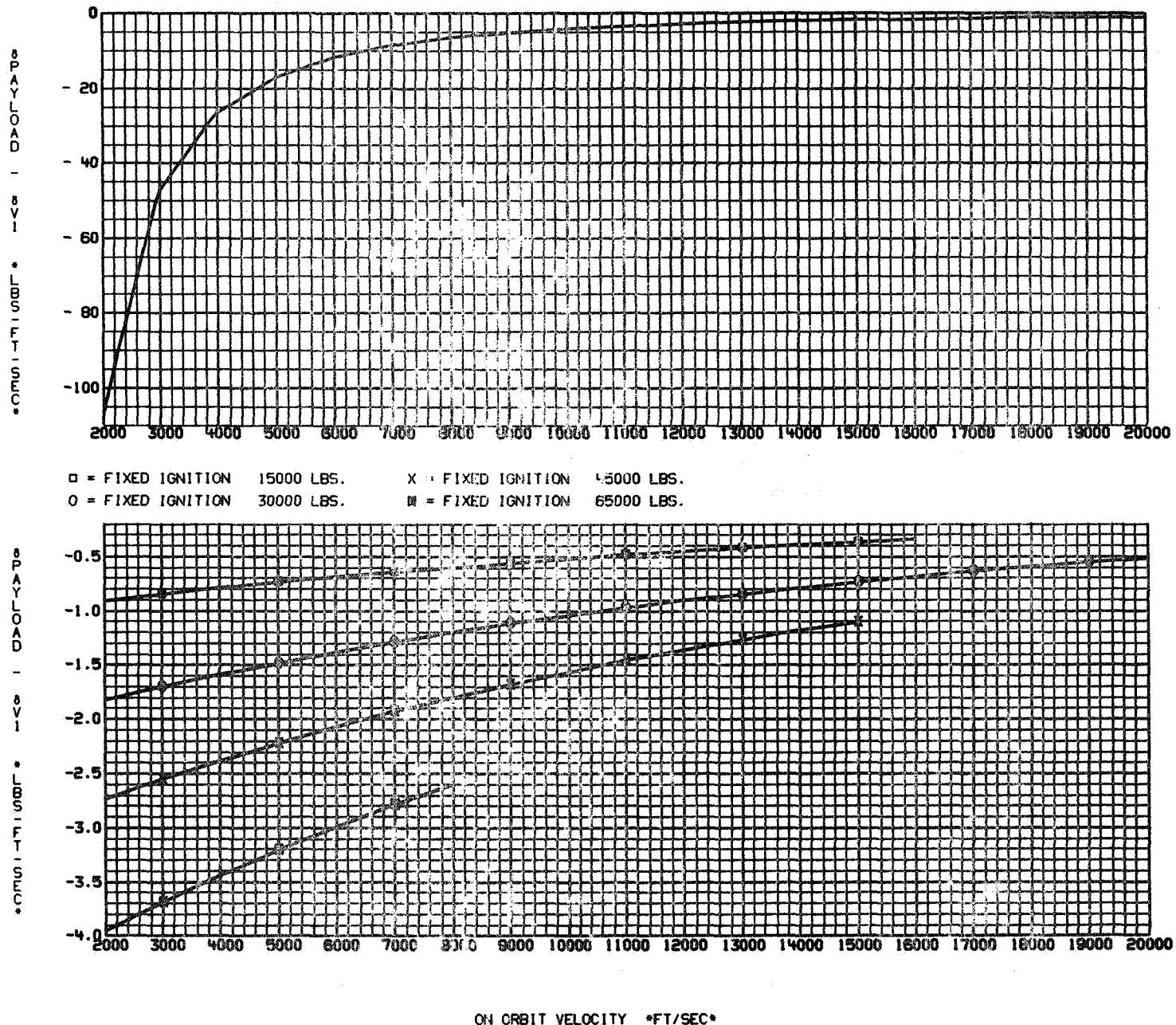


Figure 3-18

PAYLOAD DELIVERED
30000 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

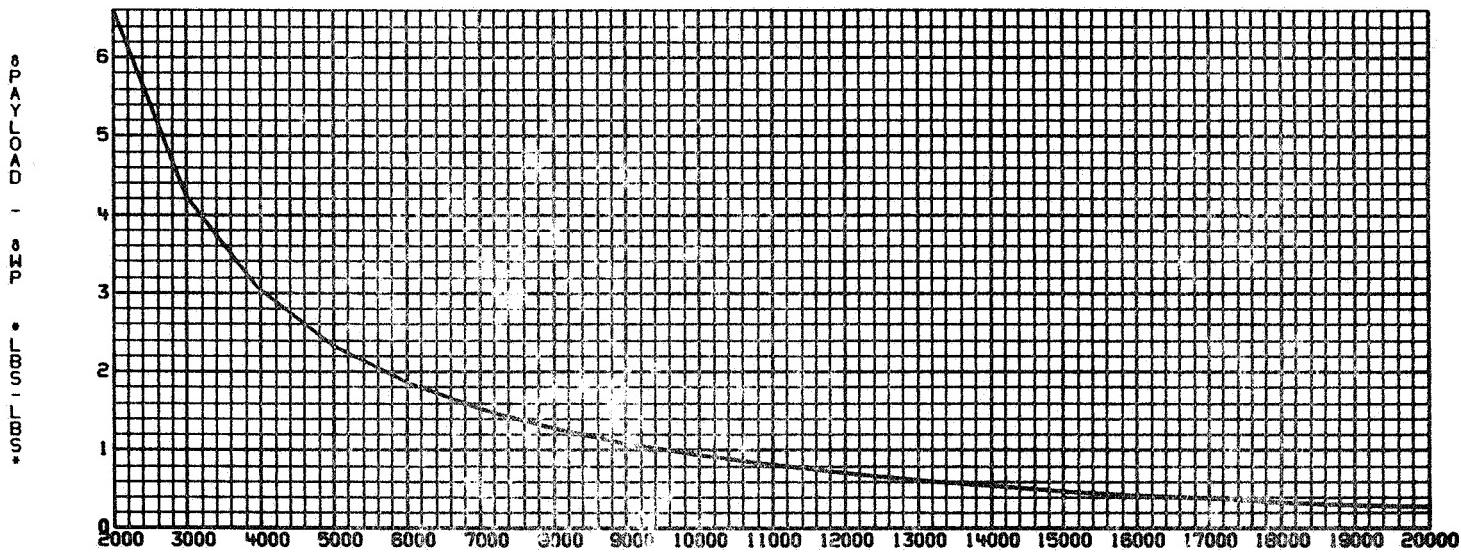
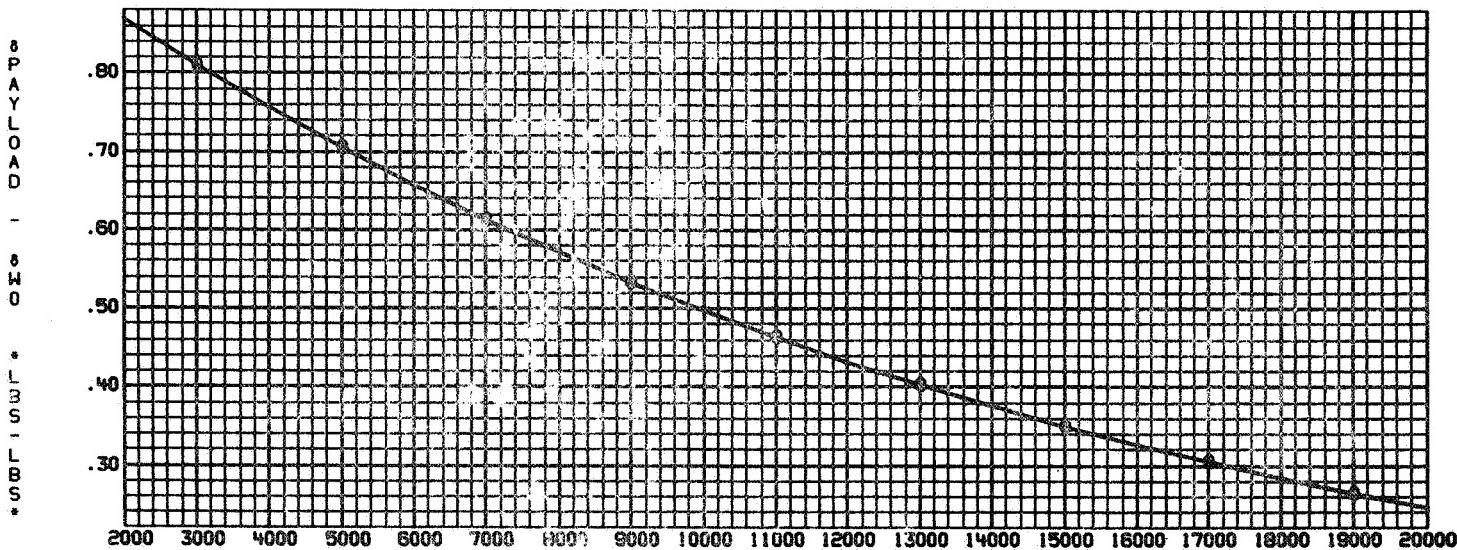


Figure 3-19

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-20

3-19

PAYLOAD DELIVERED

FIXED IGNITION WEIGHTS

EXPENDABLE TUG AND P/L

= FIXED IGNITION 15000 LBS.

X = FIXED IGNITION 45000 LBS.

X = FIXED IGNITION

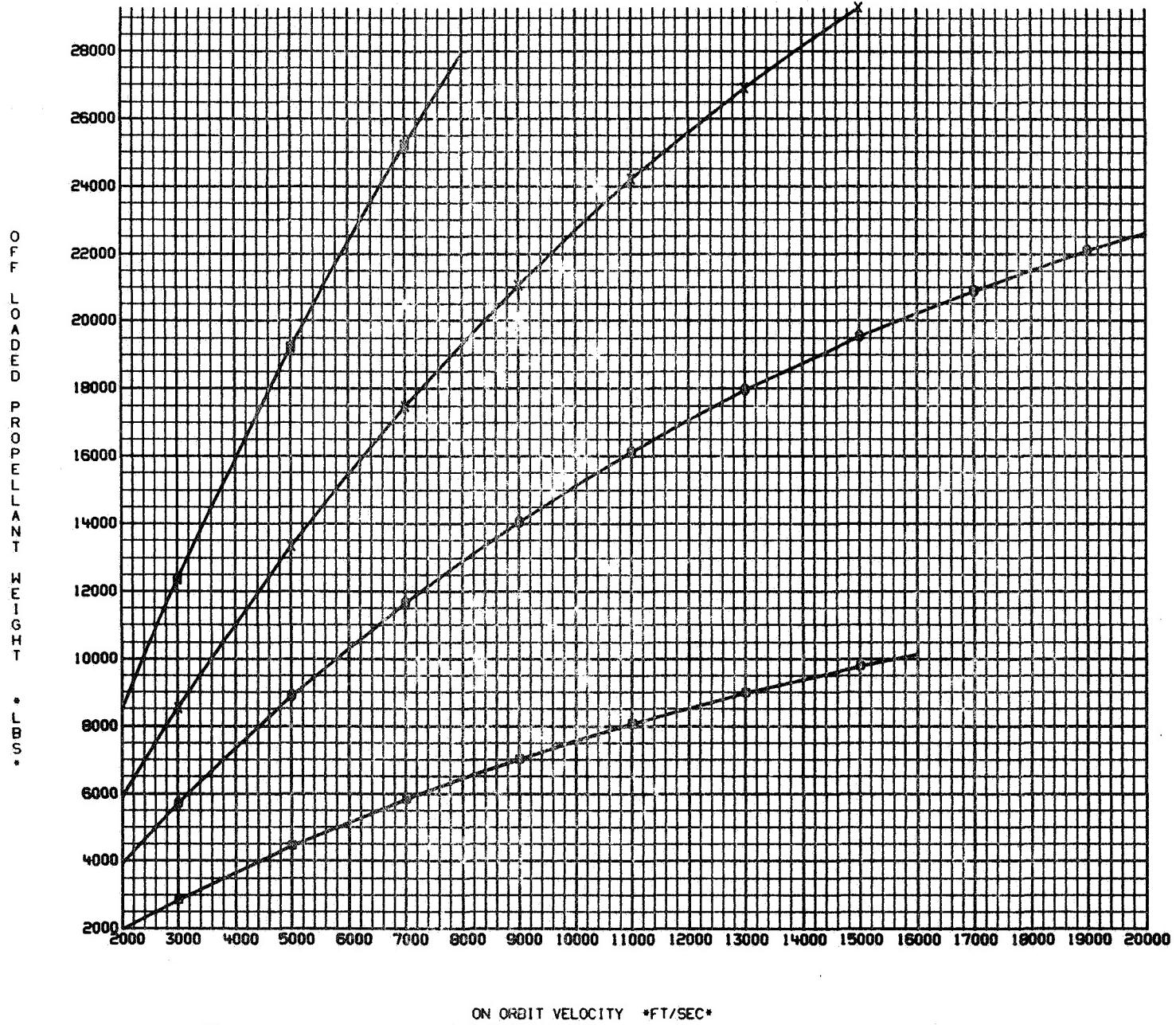


Figure 3-21

GT CENTAUR
W_P = 45,000 LB

PAYLOAD DELIVERED 45000 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 45000 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

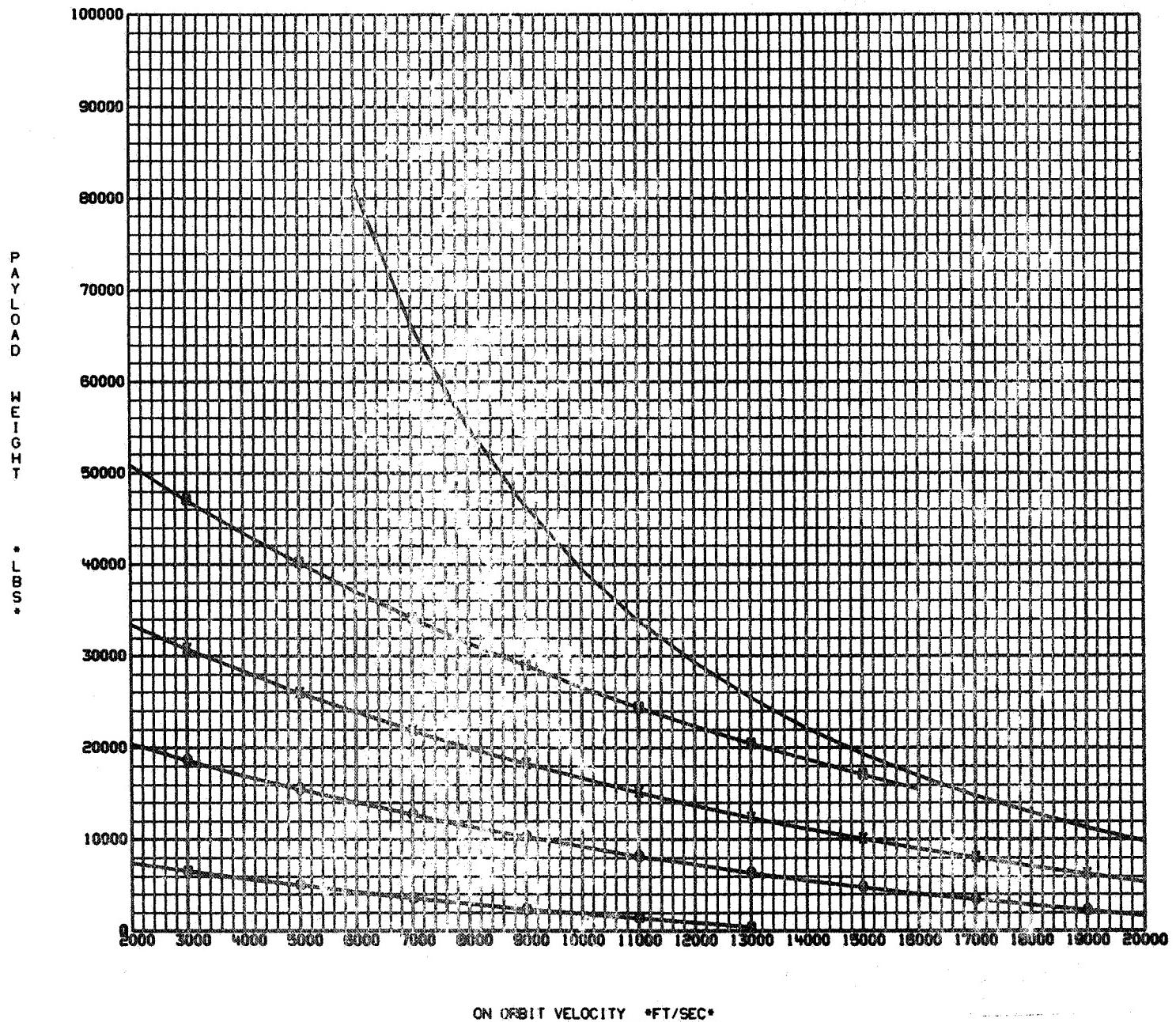


Figure 3-22

Payload delivered

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT

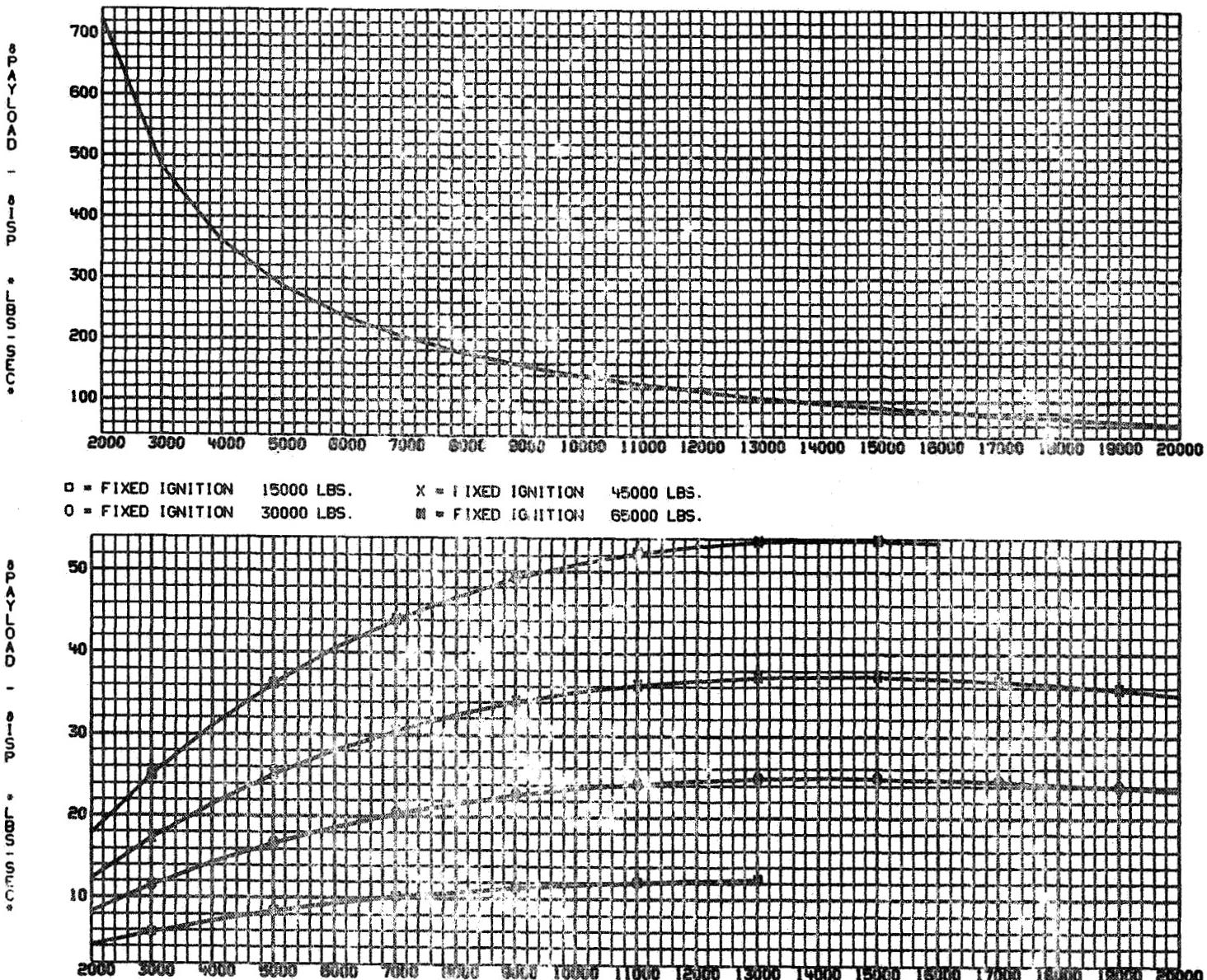
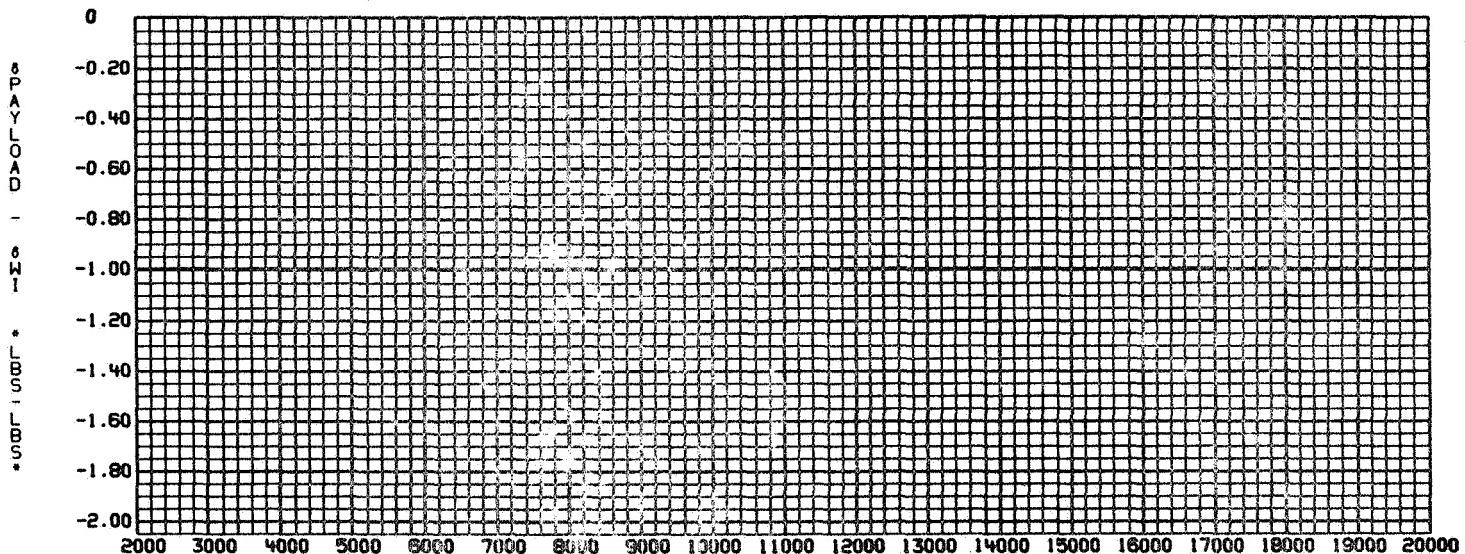


Figure 3-22

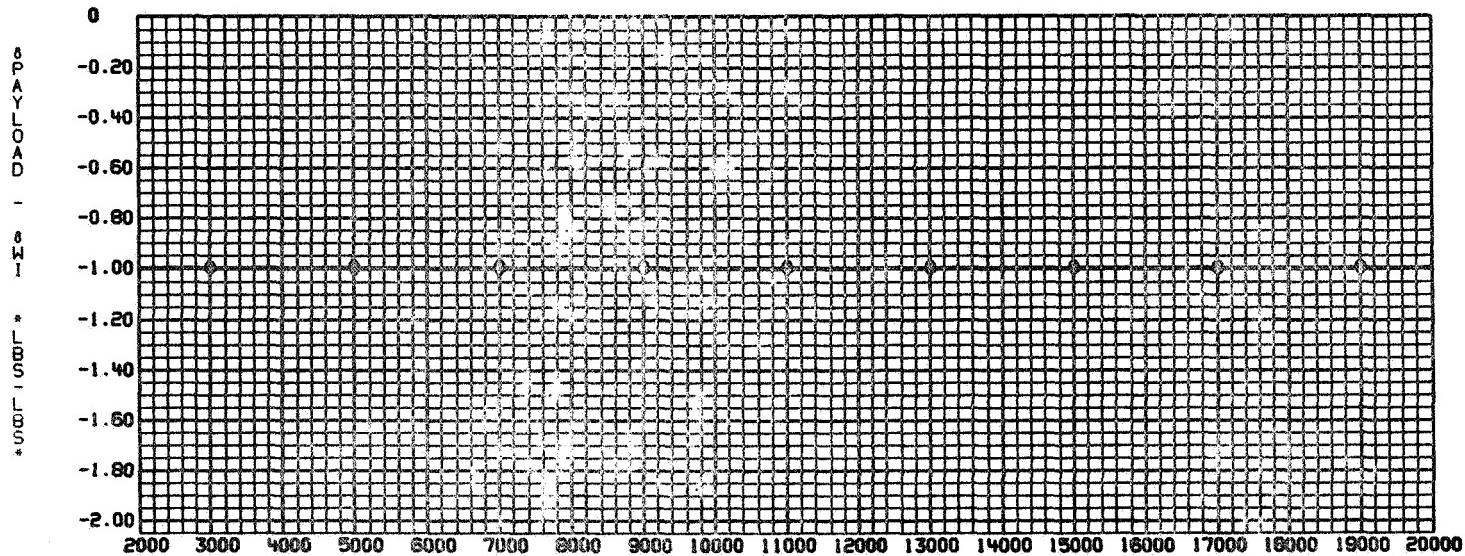
PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



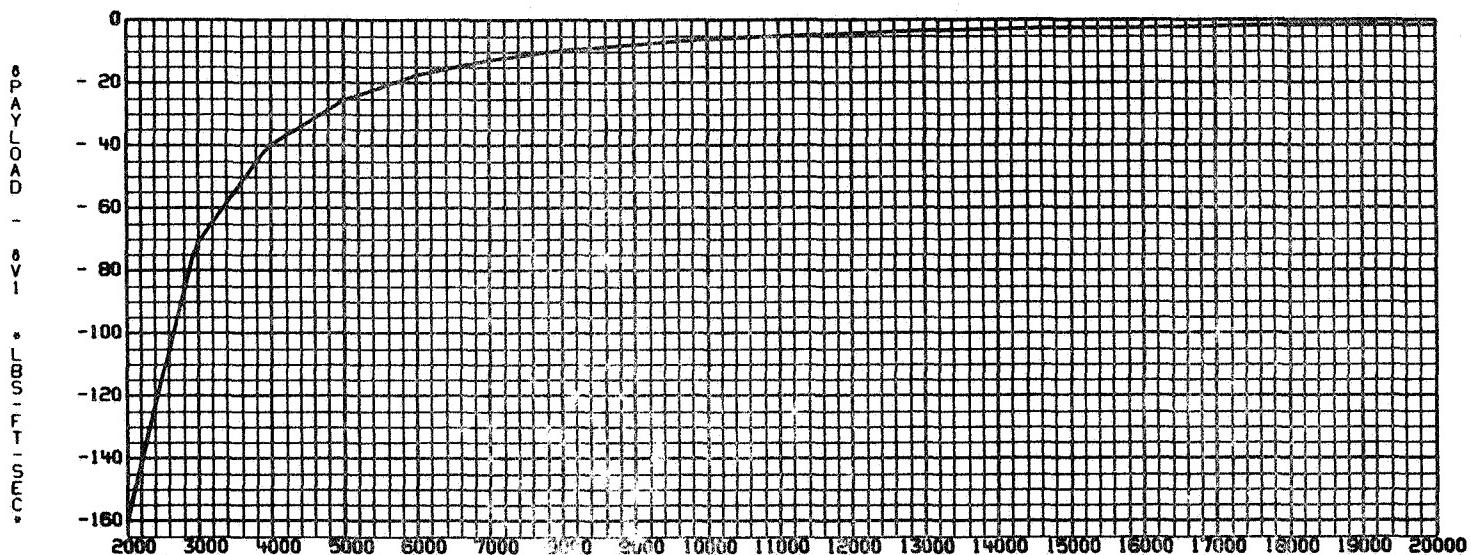
ON ORBIT VELOCITY *FT/SEC*

Figure 3-24

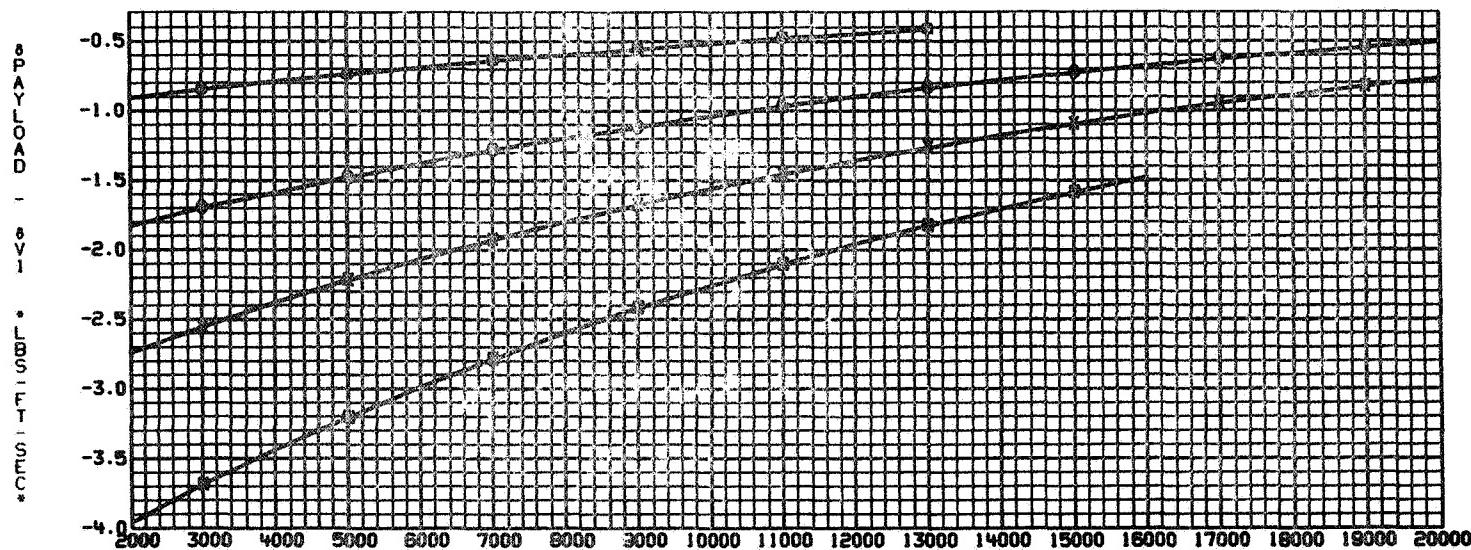
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ▨ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-25

PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT

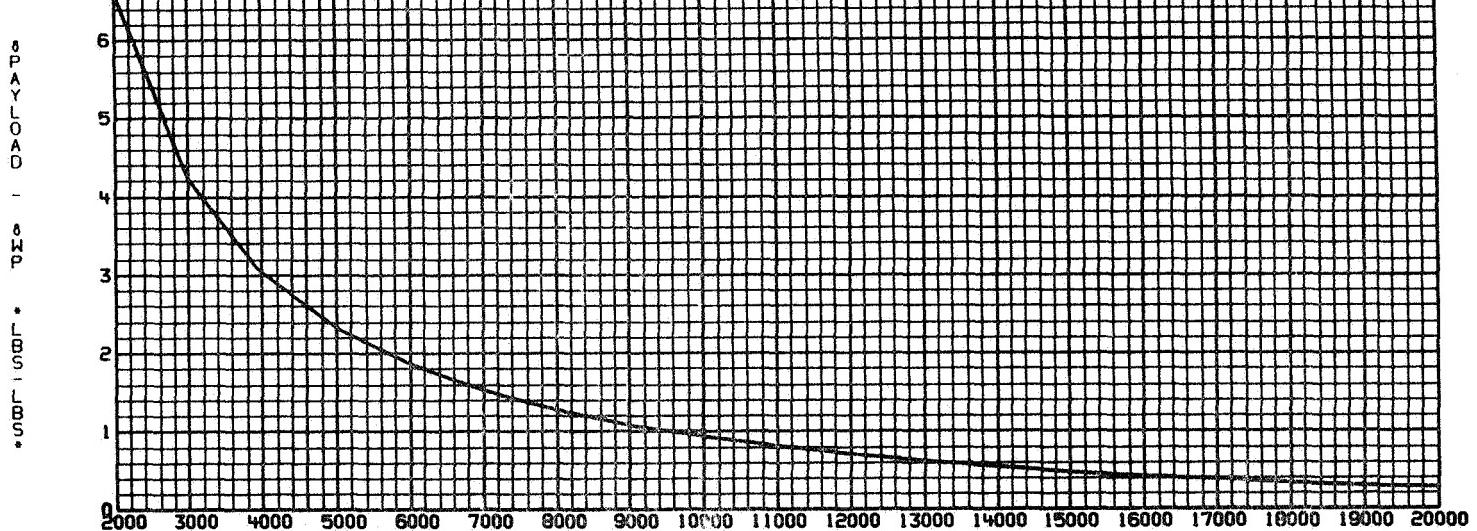
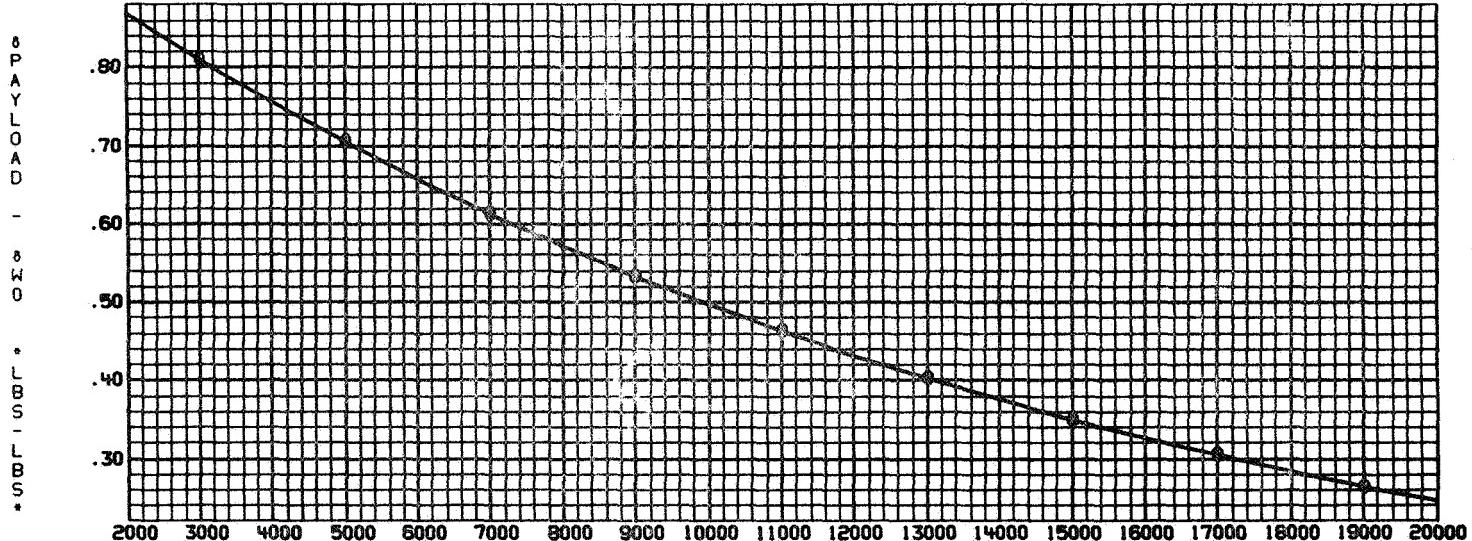


Figure 3-26

ALL FIXED IGNITION WEIGHTS



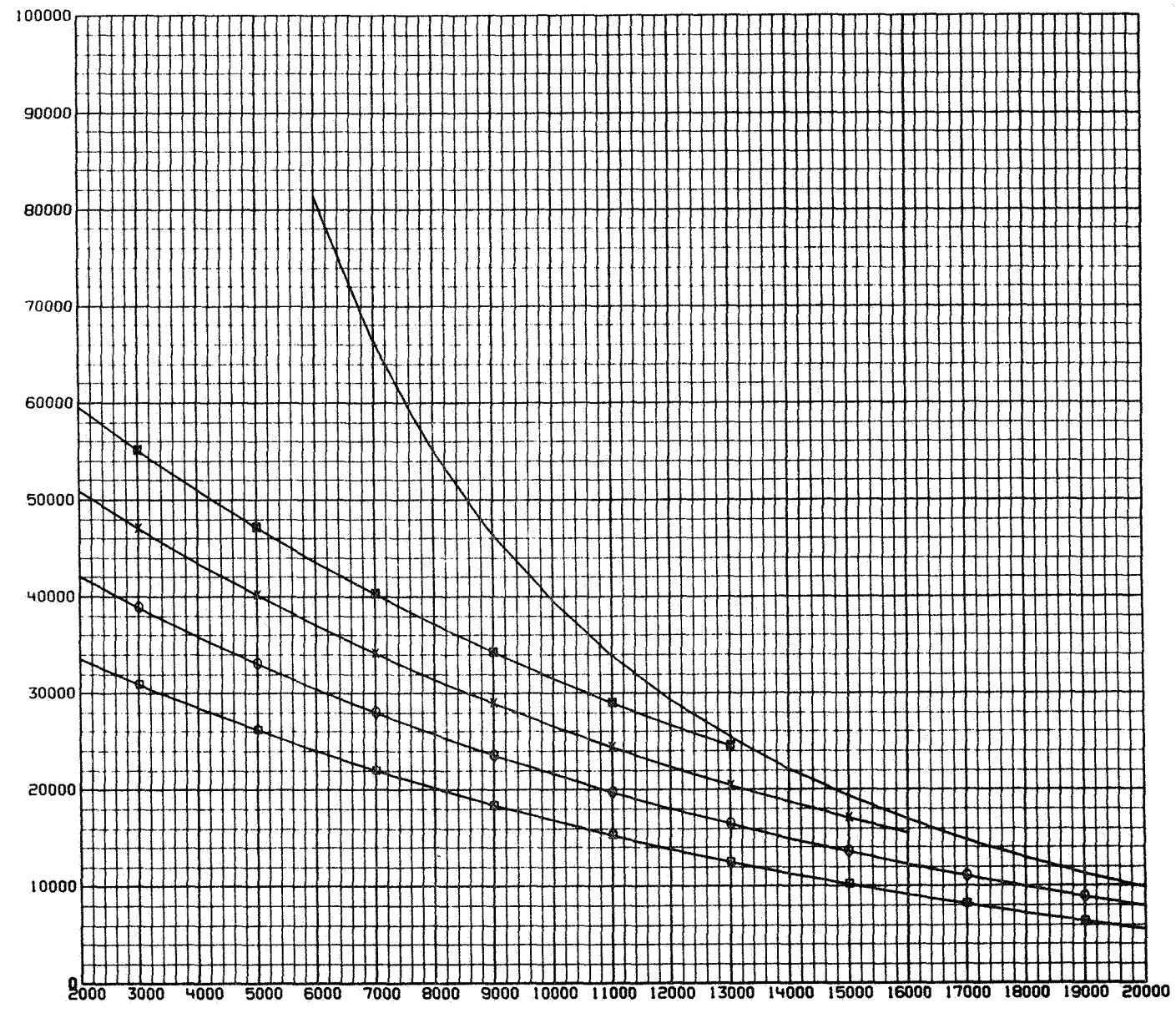
ON ORBIT VELOCITY *FT/SEC*

Figure 3-27

PAYOUT DELIVERED
- = FIXED PROPELLANT 45000 LBS.
o = FIXED IGNITION 45000 LBS.
x = FIXED IGNITION 65000 LBS.

45000 LBS. FIXED PROPELLANT WEIGHT
o = FIXED IGNITION 55000 LBS.
x = FIXED IGNITION 65000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 75000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-28

MODE 1

PAYOUT RETURNED	50158 LBS. FIXED PROPELLANT WEIGHT	ROUND TRIPPED P/L CAPABILITY
FIXED PROPELLANT 50158 LBS.	O = FIXED IGNITION 30000 LBS.	W = FIXED IGNITION 65000 LBS.
FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

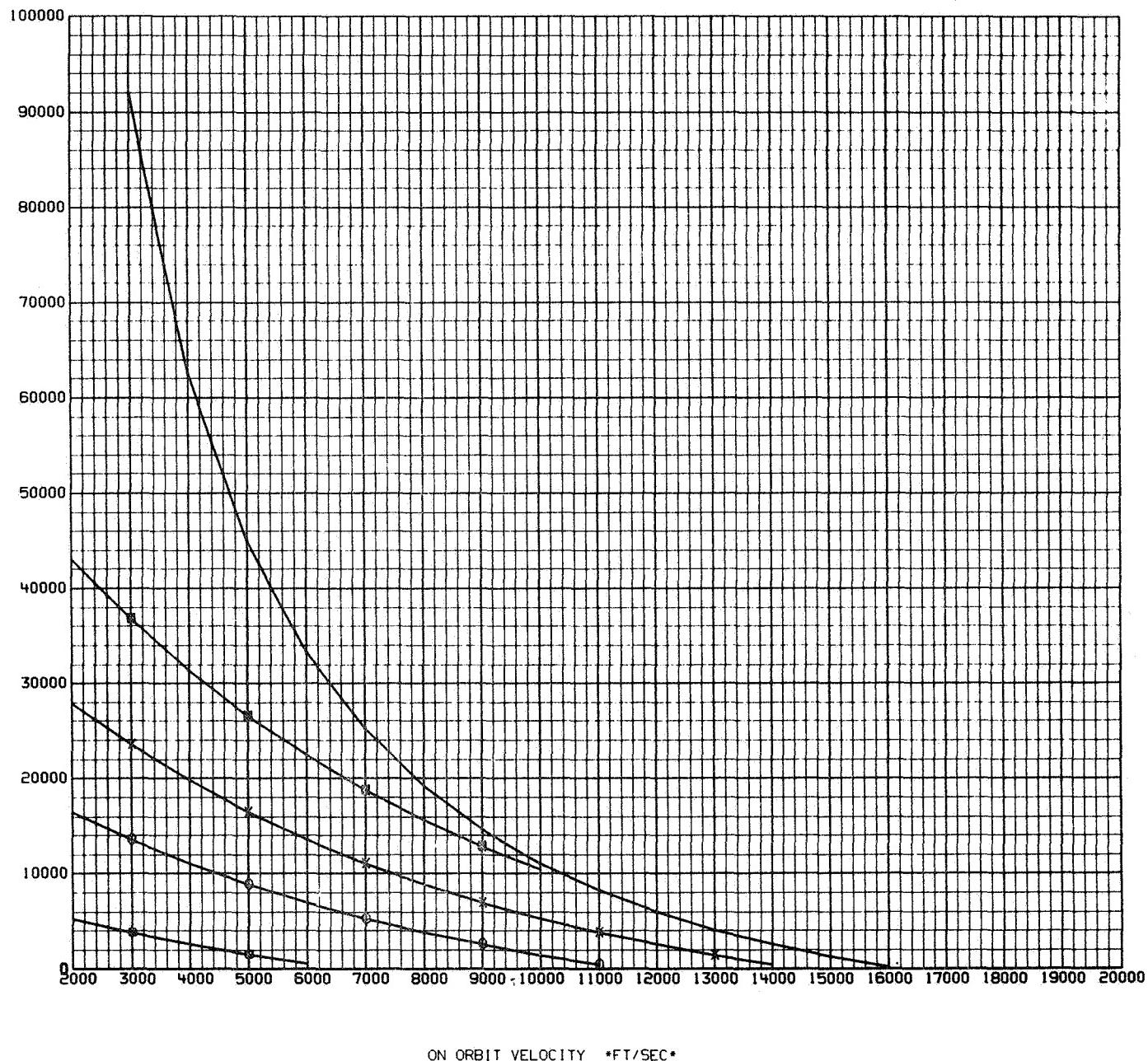
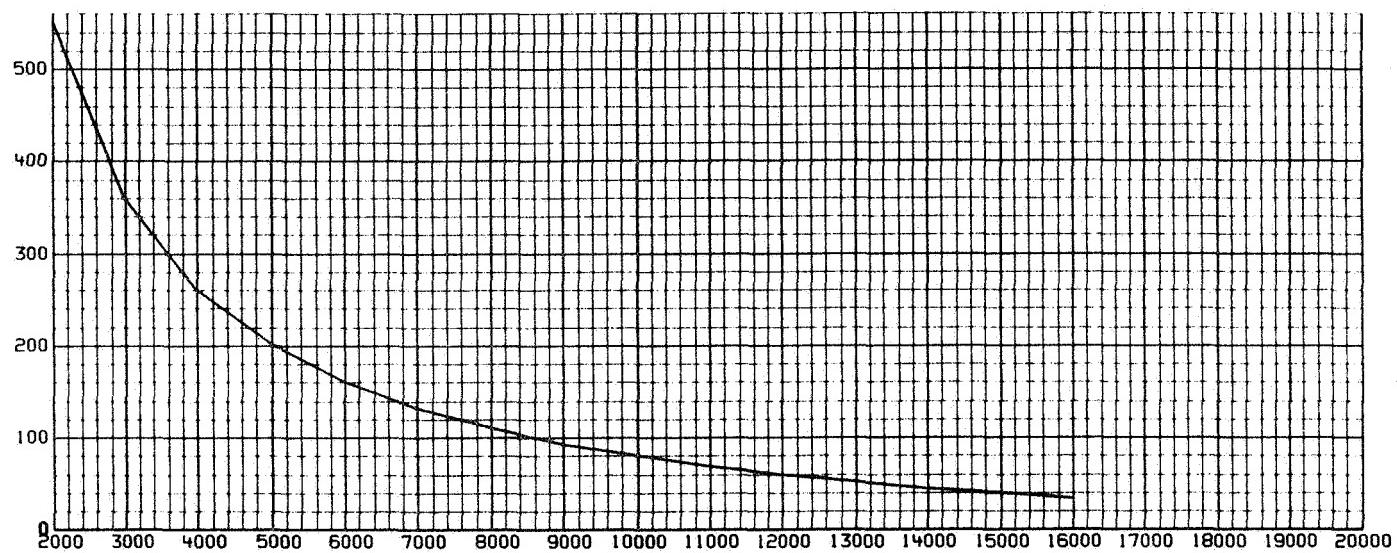


Figure 3-29

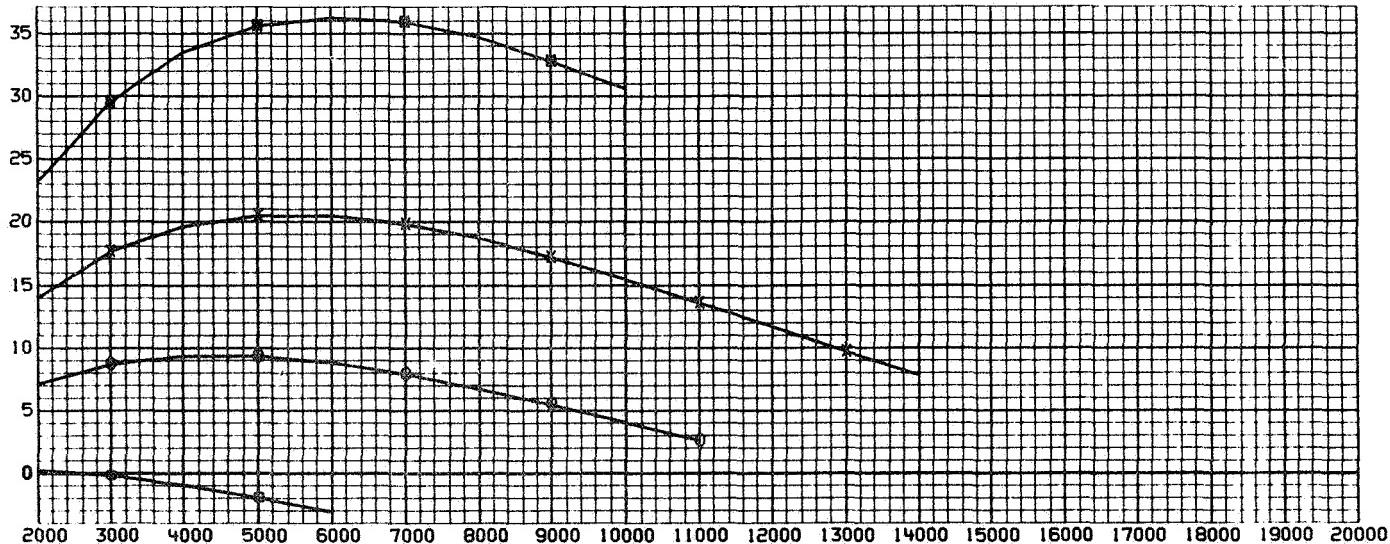
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

MOTOR LBS. FIXED PROPELLANT WEIGHT



D = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



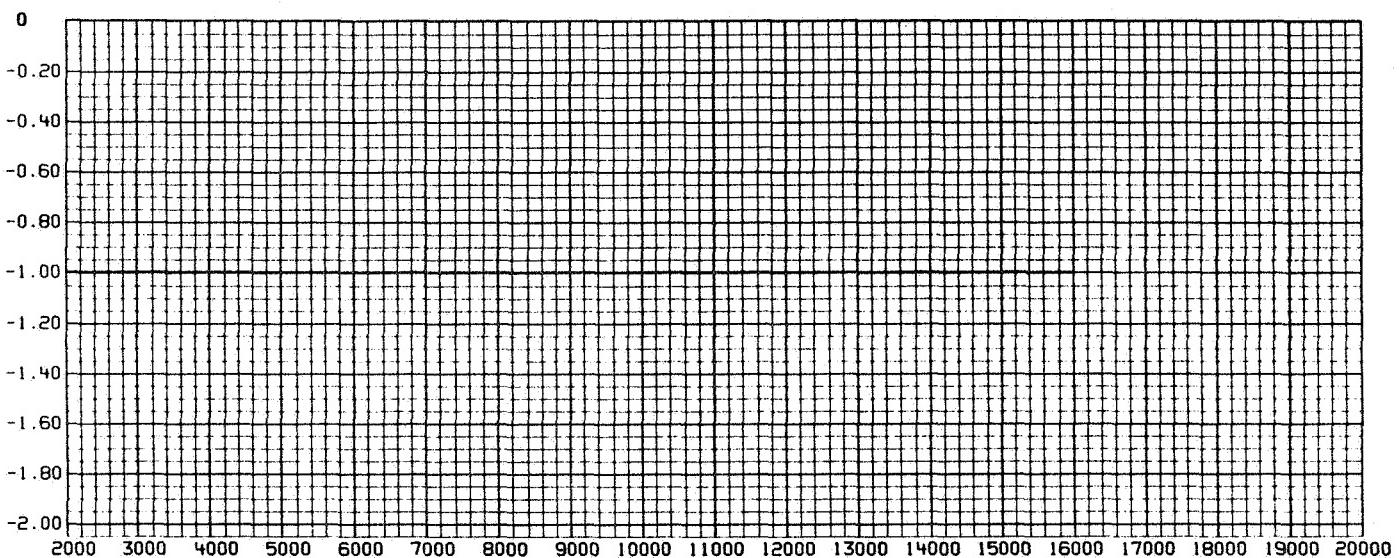
ON ORBIT VELOCITY *FT/SEC*

Figure 3-30

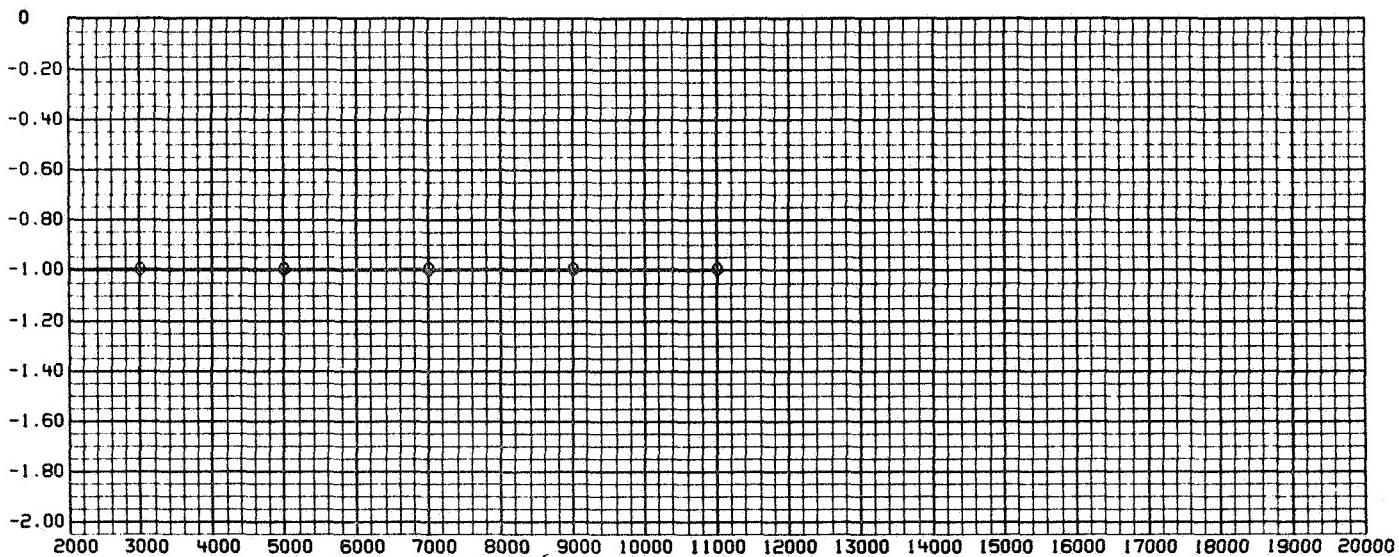
Payload Delivered

ROUND TRIPPED P/L CAPABILITY

OFFICE LINE: FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



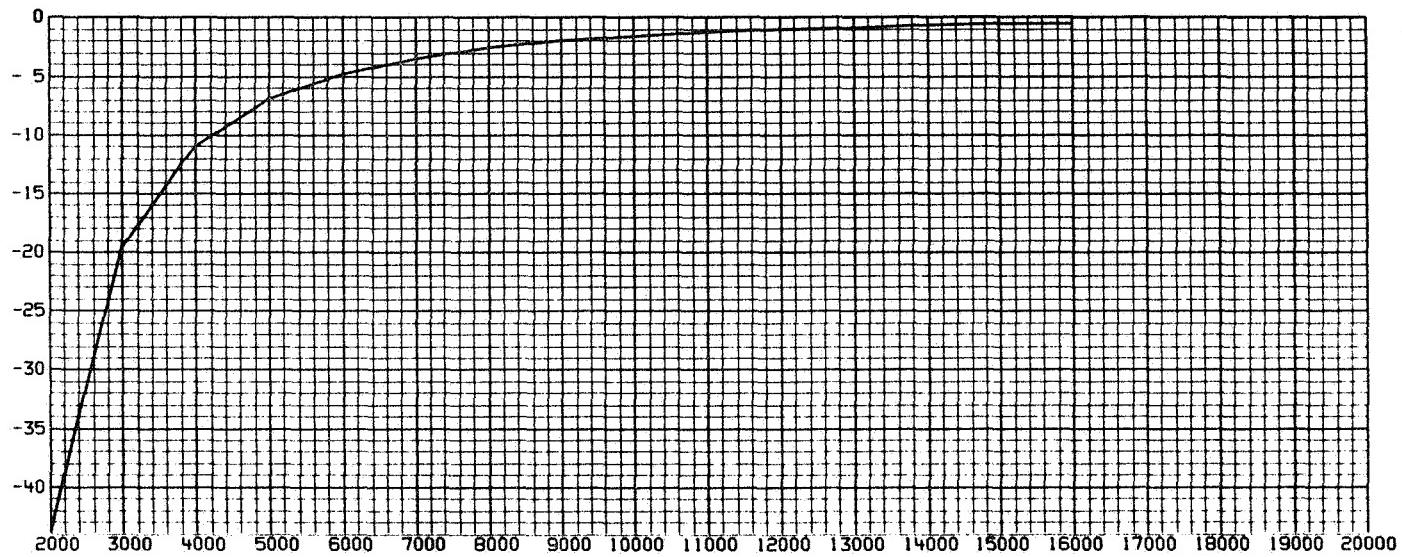
ON ORBIT VELOCITY *FT/SEC*

Figure 3-31

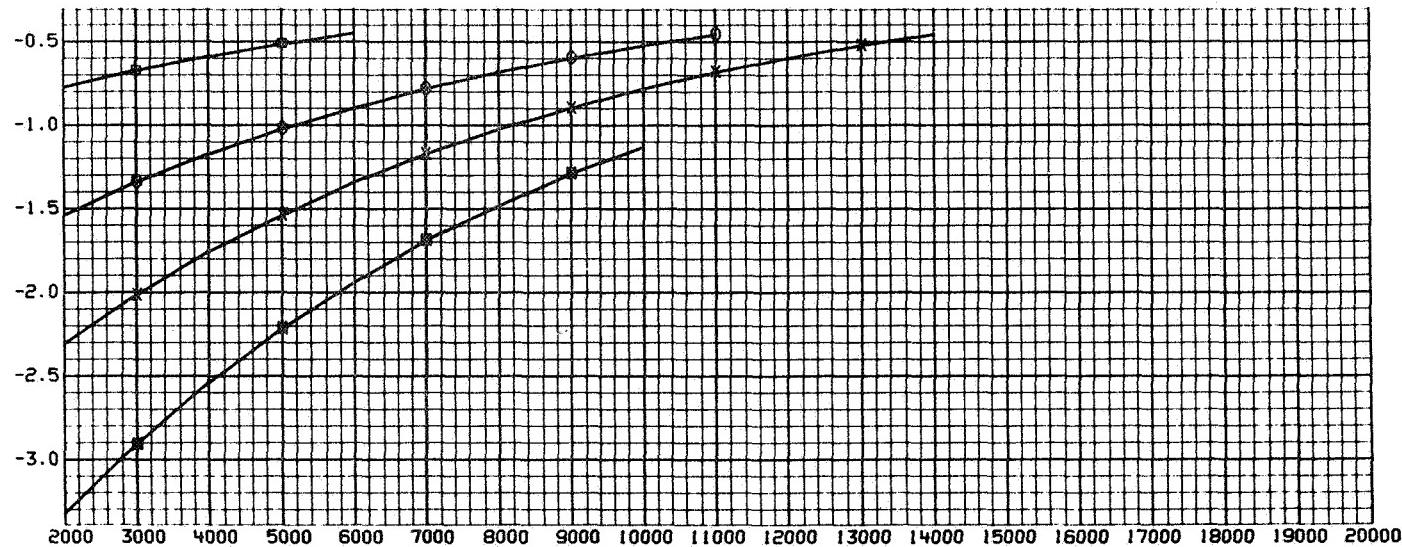
PAYOUT DELIVERED

ROUND TRIPPED P.L. CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT



○ = FIXED IGNITION 15000 LBS. × = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



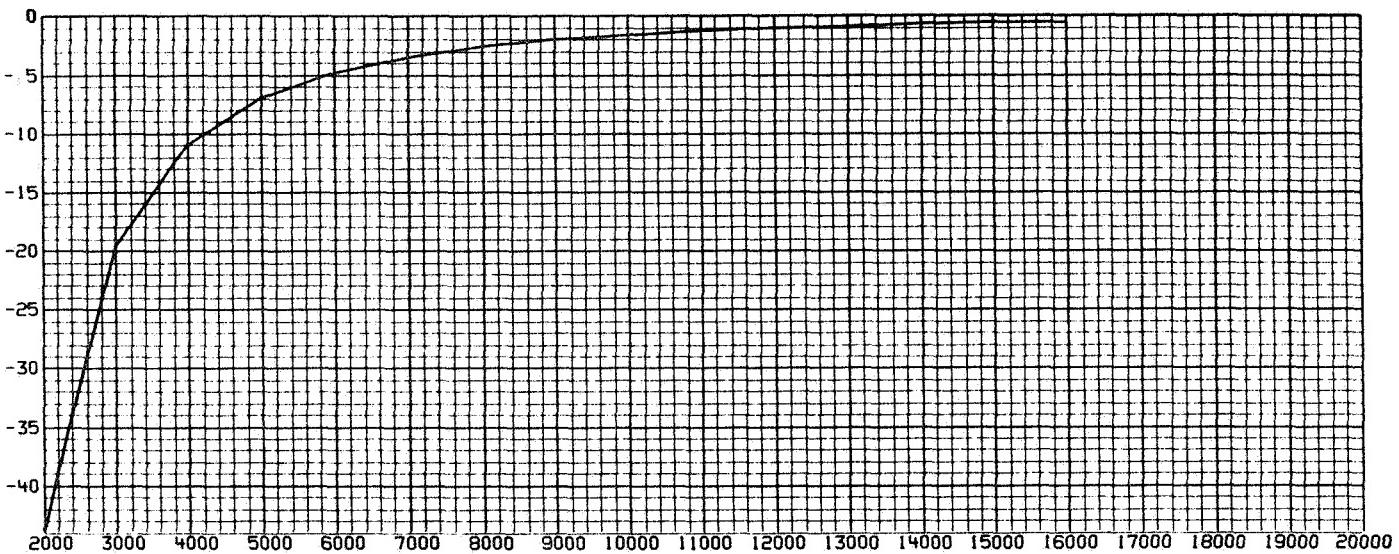
ON ORBIT VELOCITY *FT/SEC*

Figure 3-32

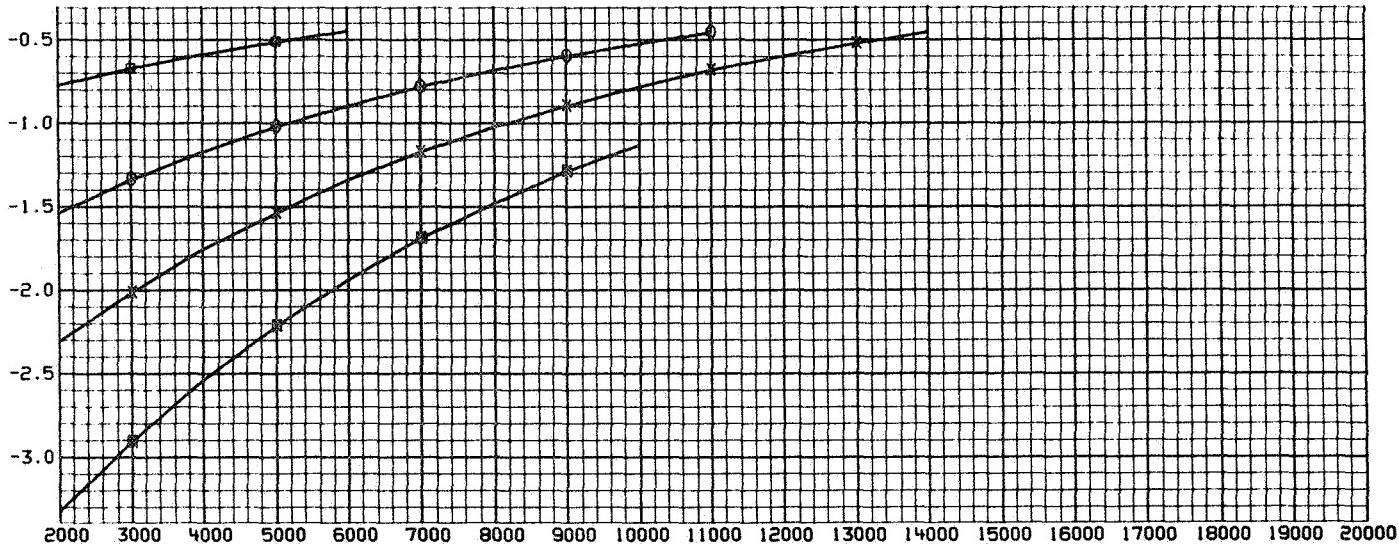
PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

SUPERFLU. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-33

PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

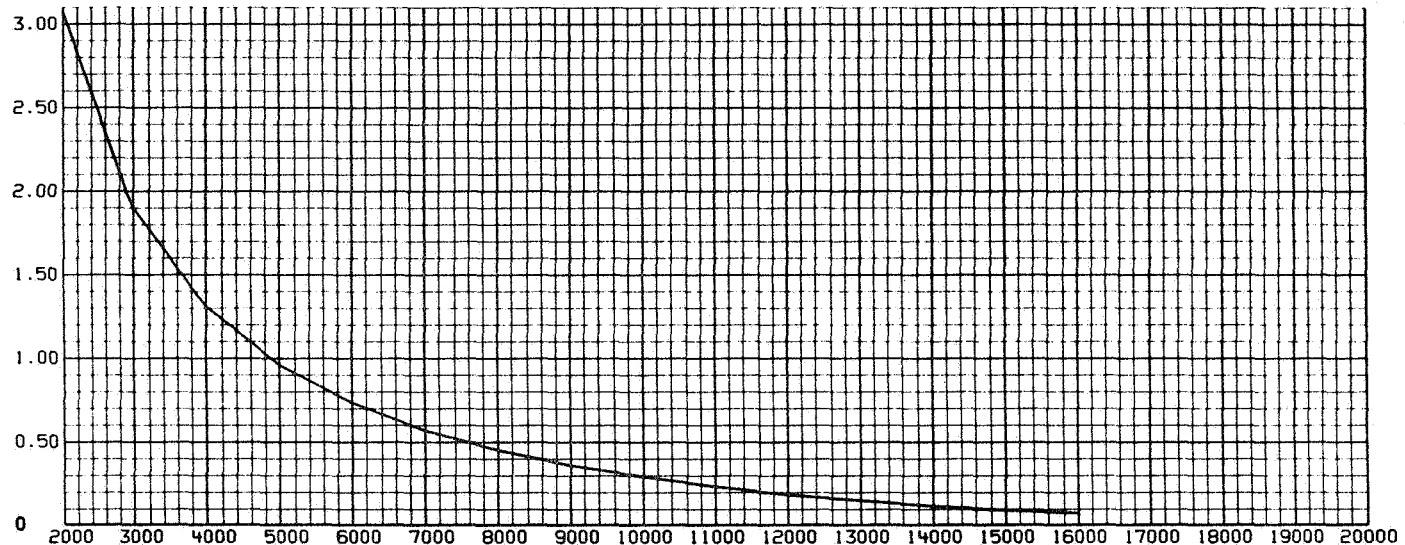
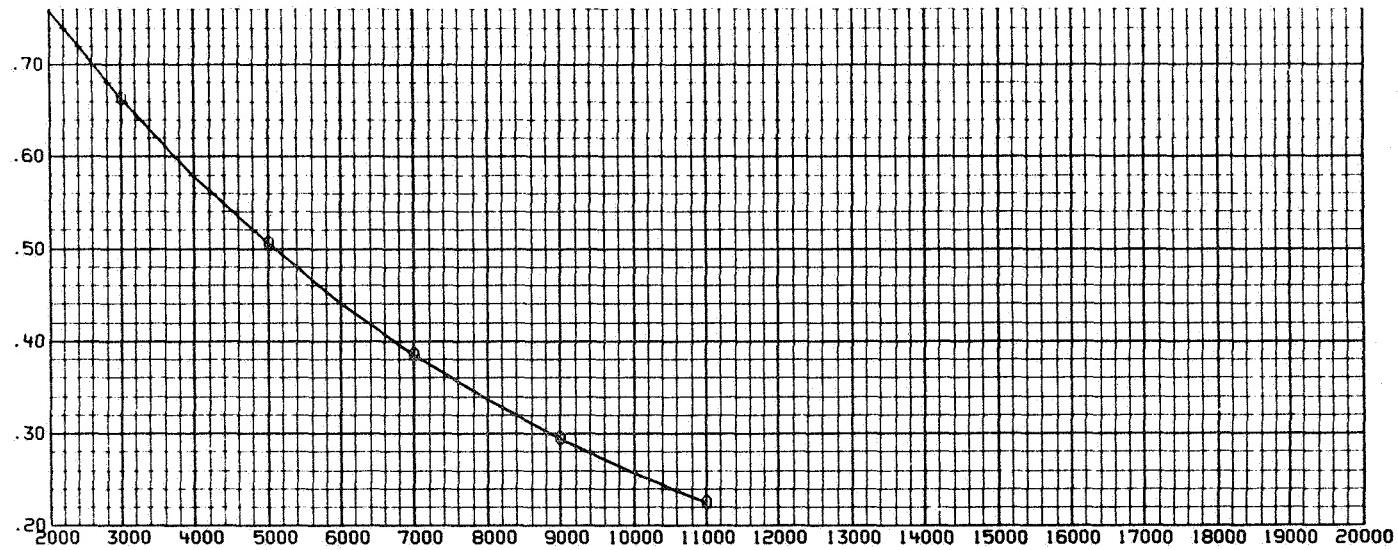


Figure 3-34

ALL FIXED TARIFF WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-35

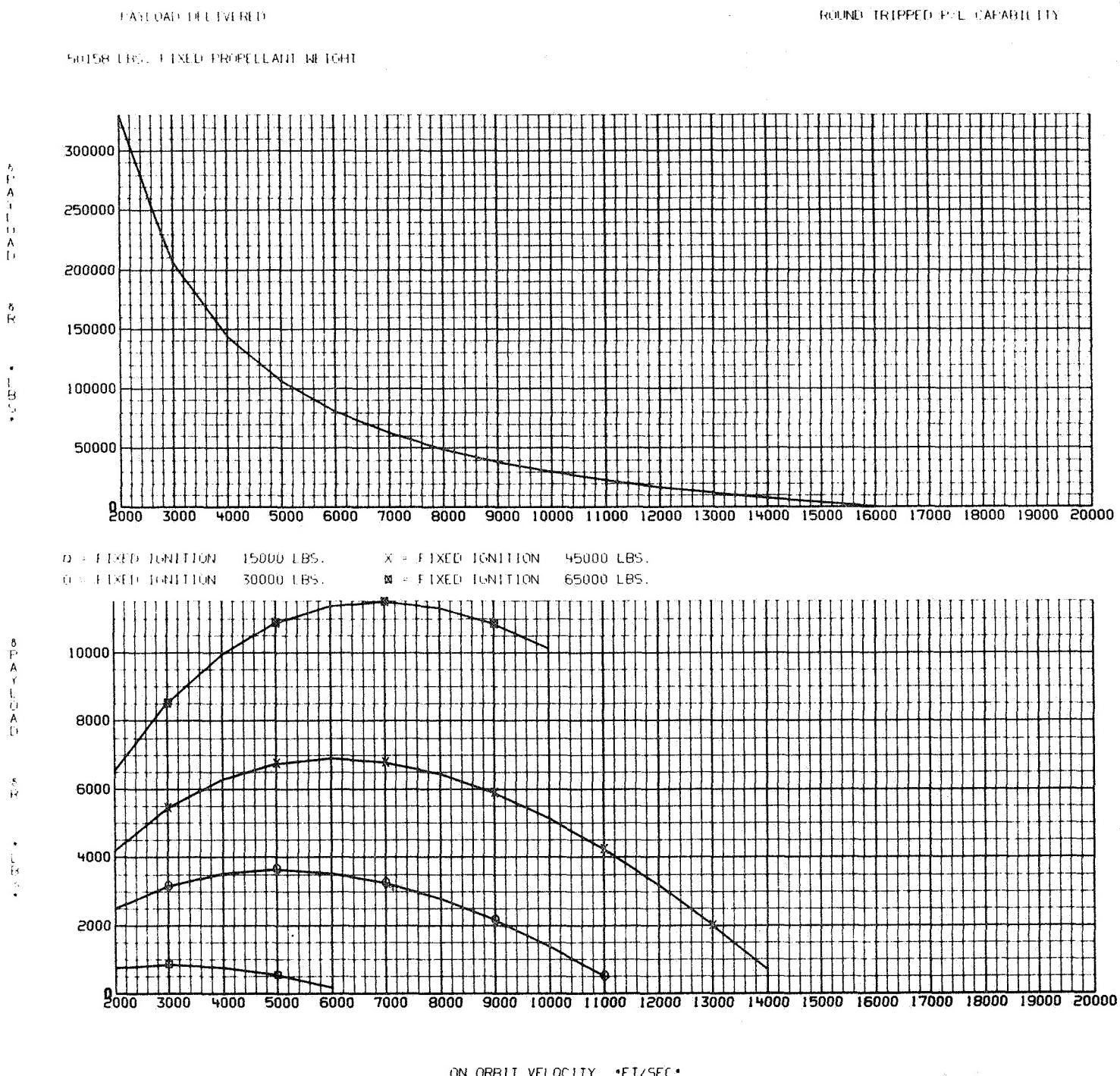


Figure 3-36

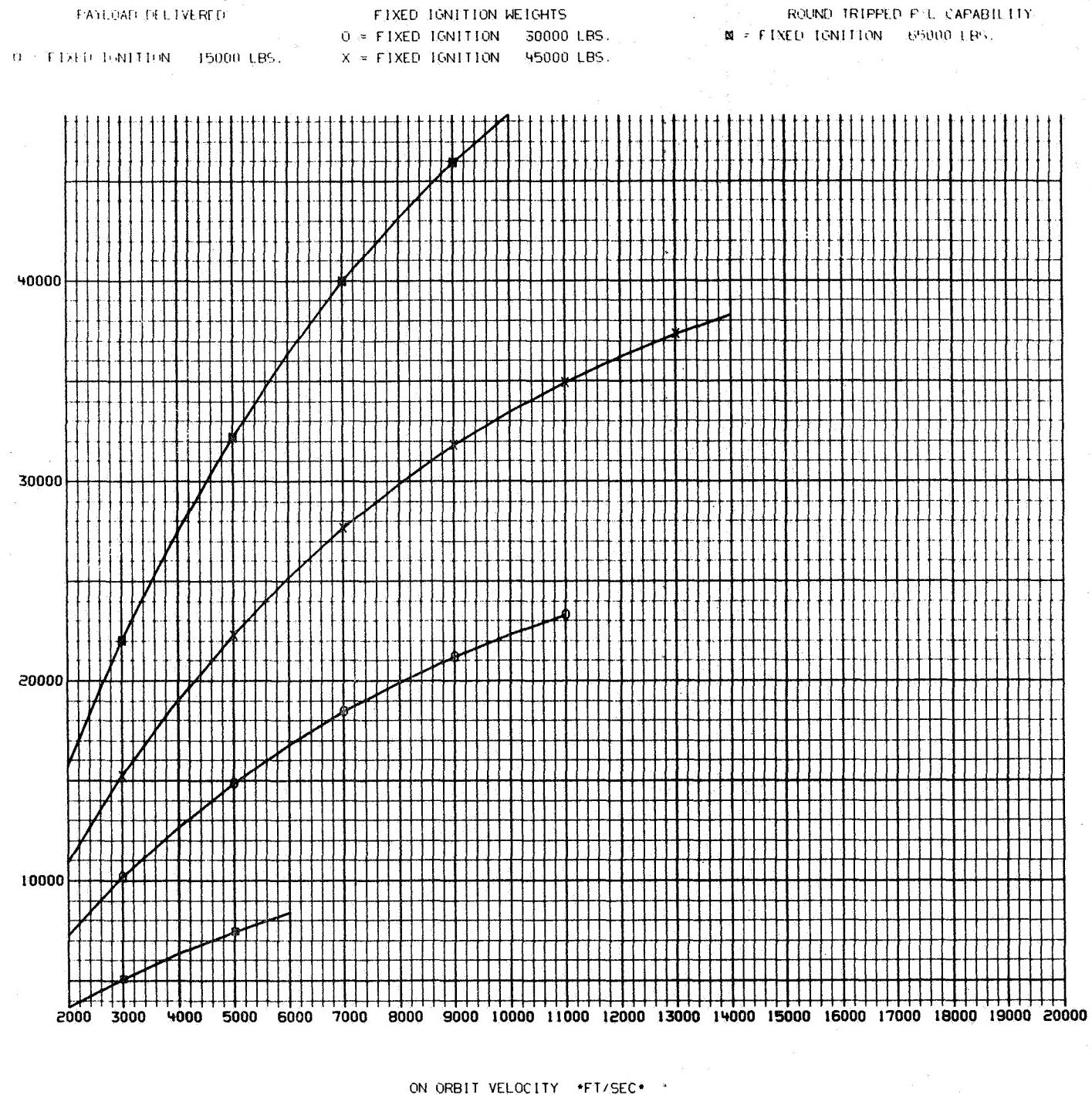


Figure 3-37

MODE 2

PAYLOAD RETURNED
• = FIXED PROPELLANT 50158 LBS.
□ = FIXED IGNITION 45000 LBS.

50158 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 55000 LBS.
X = FIXED IGNITION 65000 LBS.

TUG - P/L RETRIEVAL CAPABILITY
■ * FIXED IGNITION 75000 LBS.

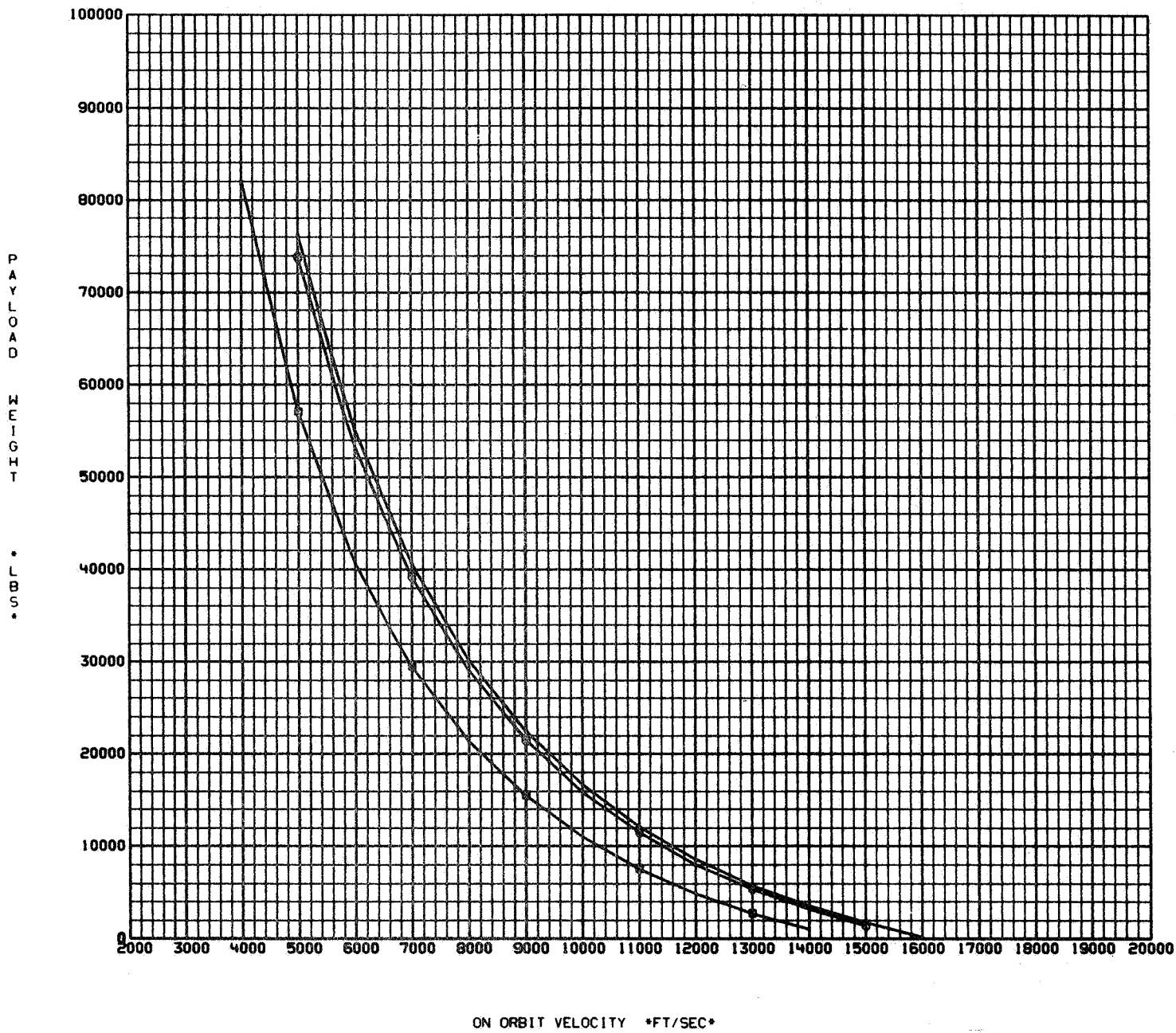


Figure 3-38

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

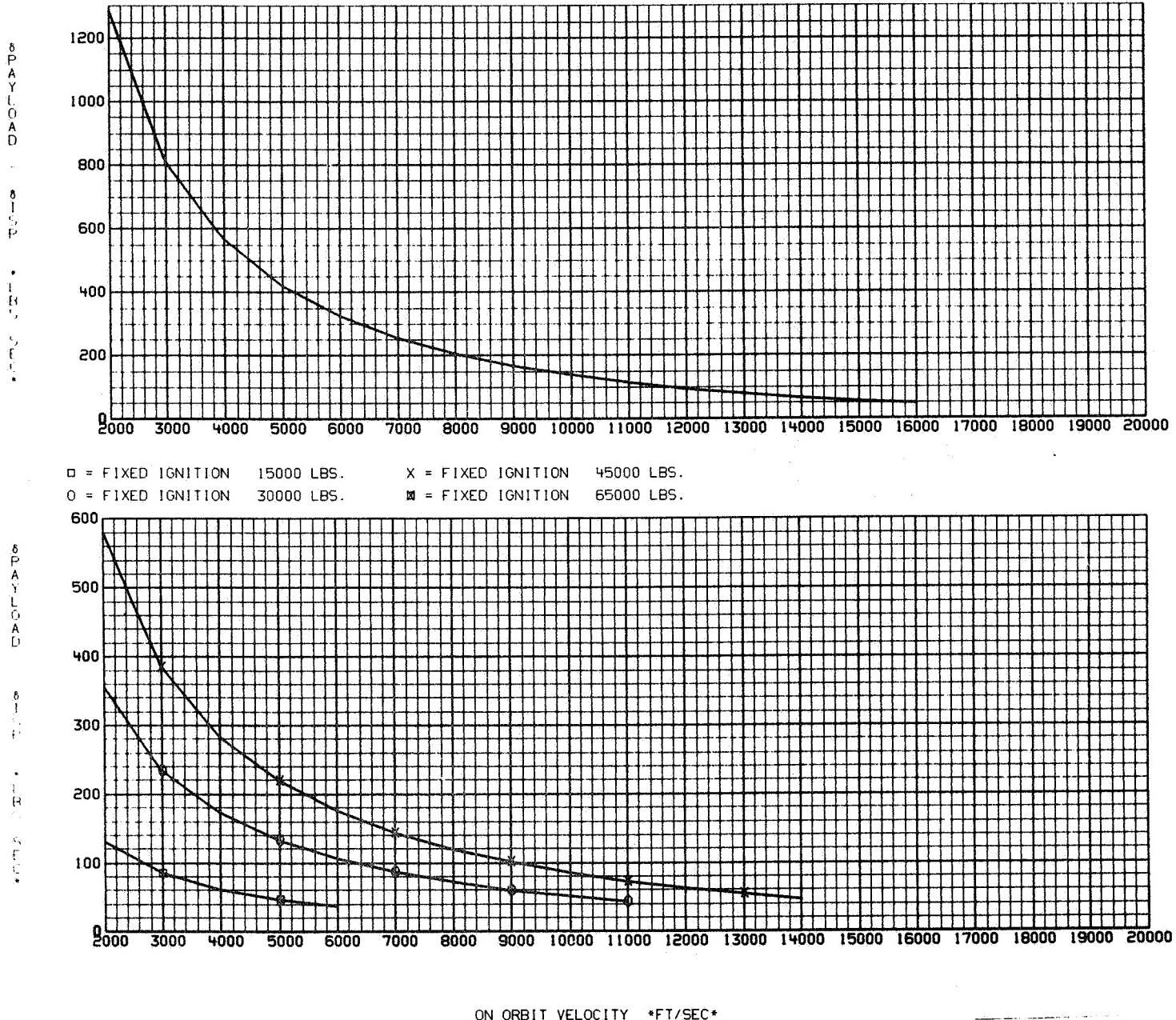
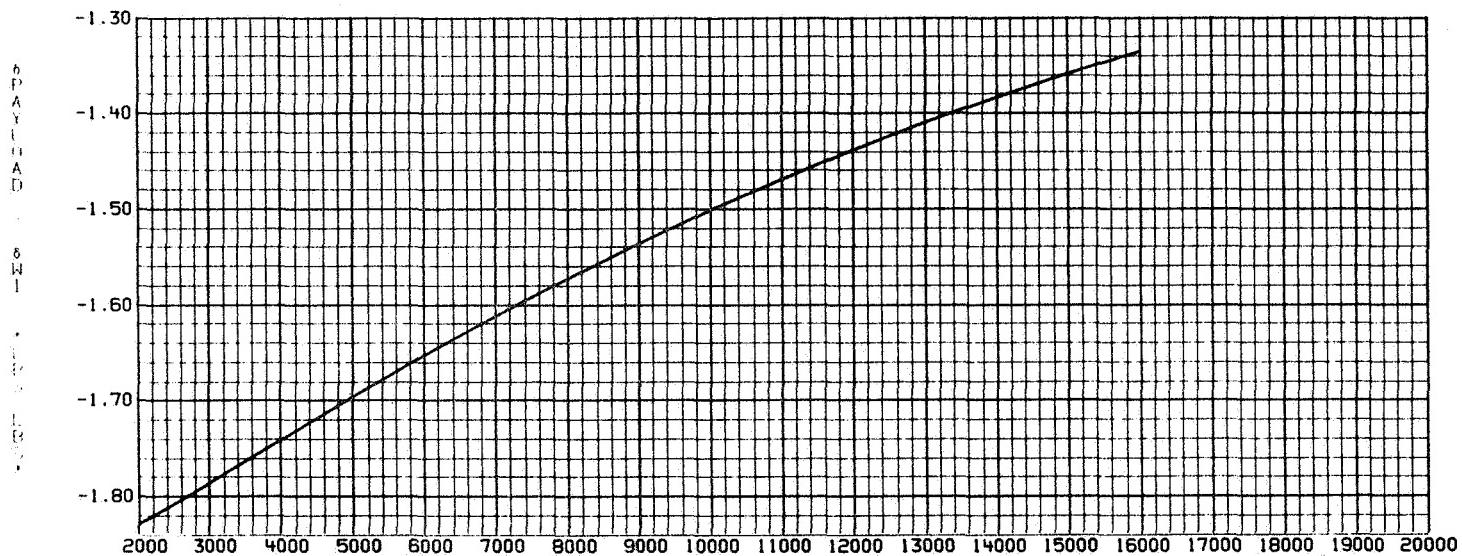


Figure 3-39

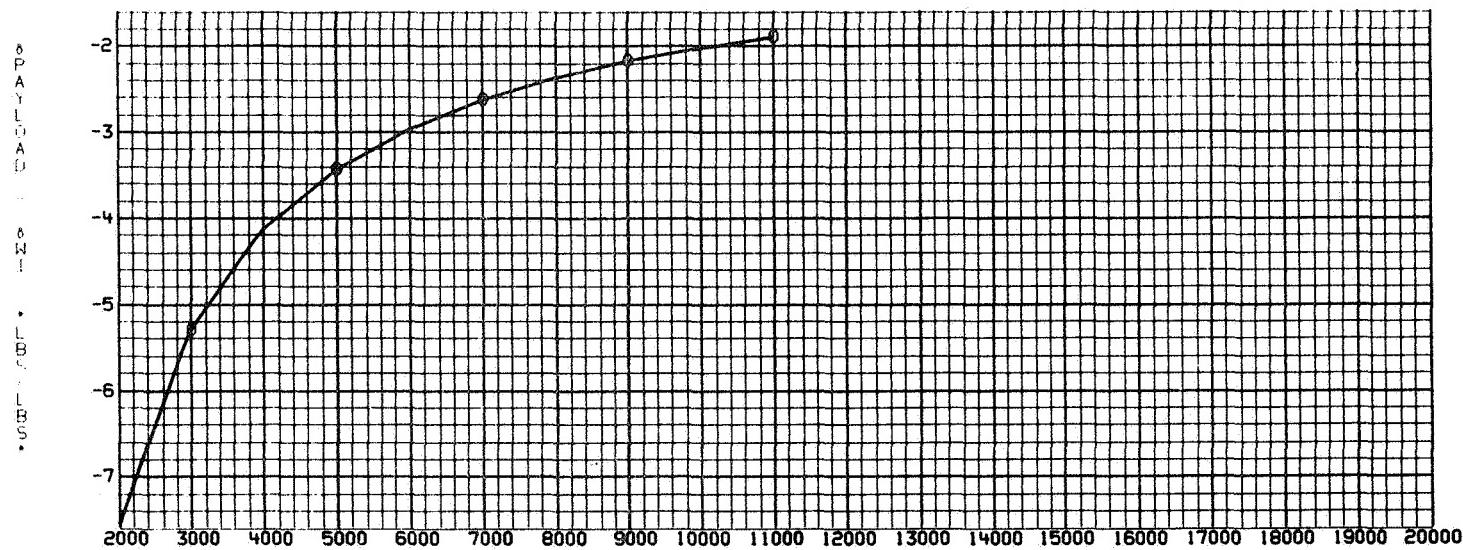
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

5000LB. EBW. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-40

PAYLOAD RETURNED

TUG - P/E RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

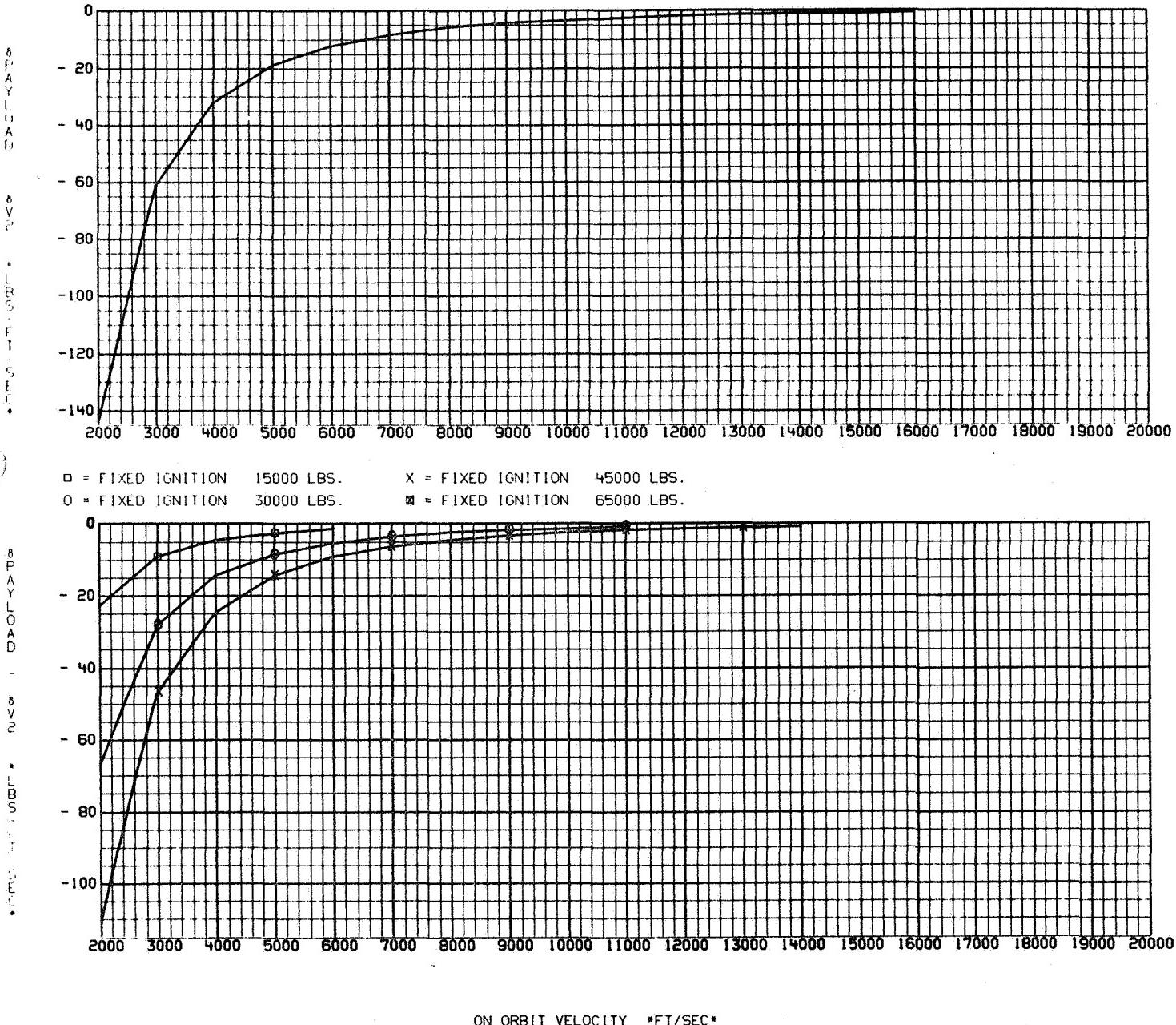


Figure 3-41

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

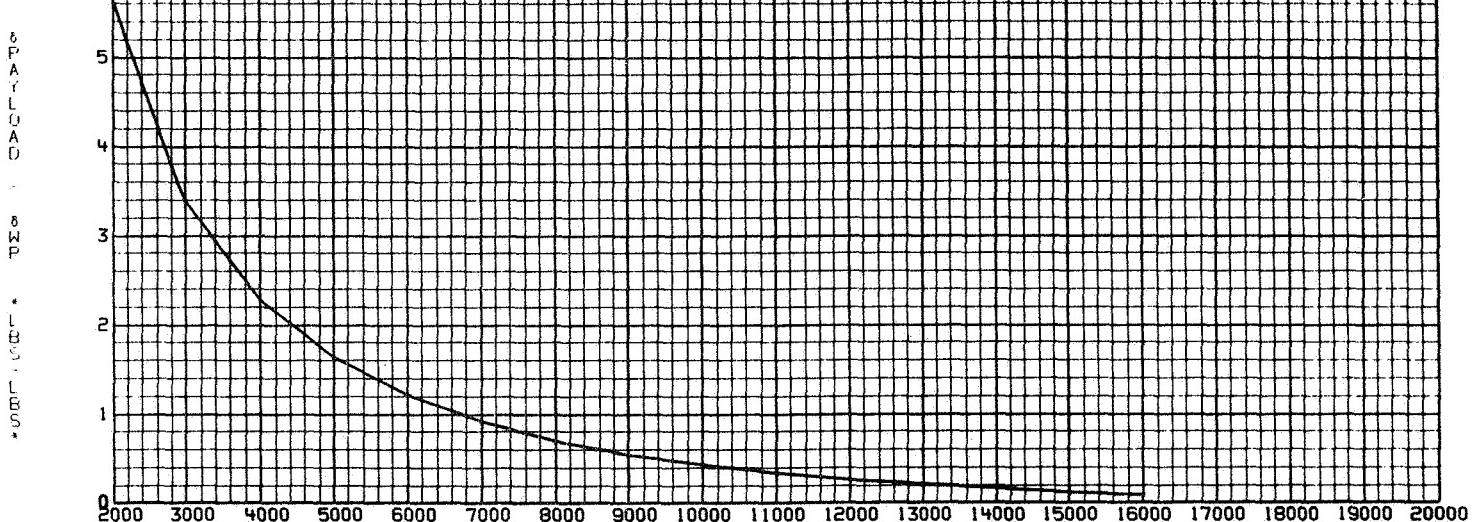
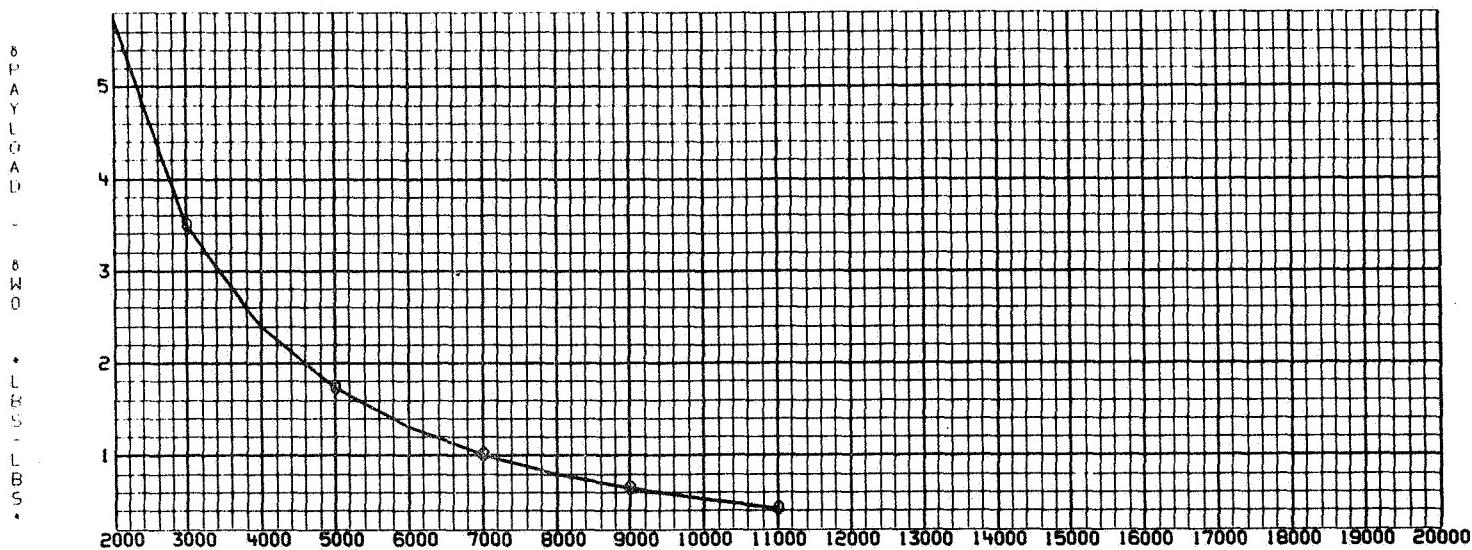


Figure 3-42

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-43

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-44

MODE 3

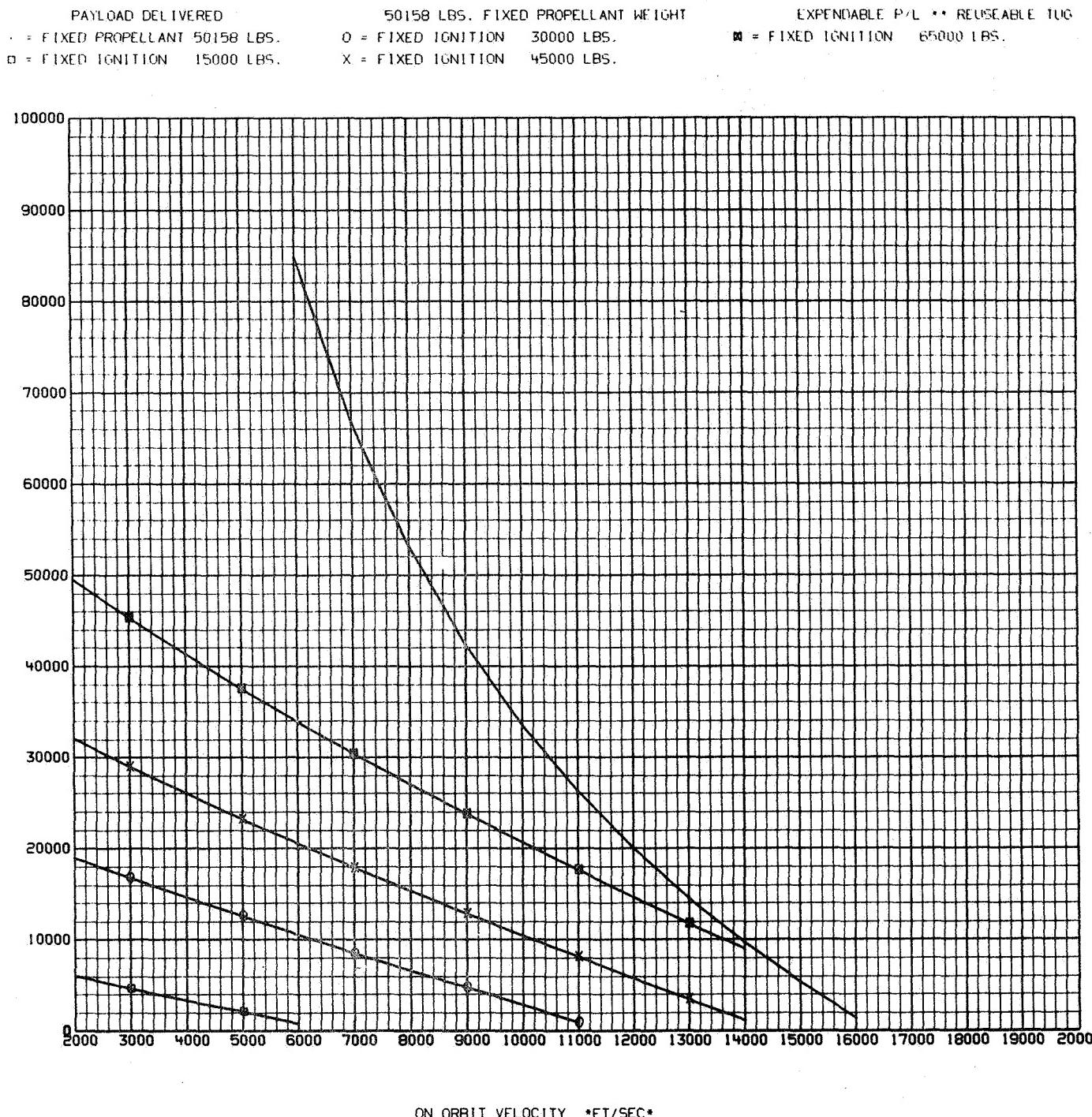
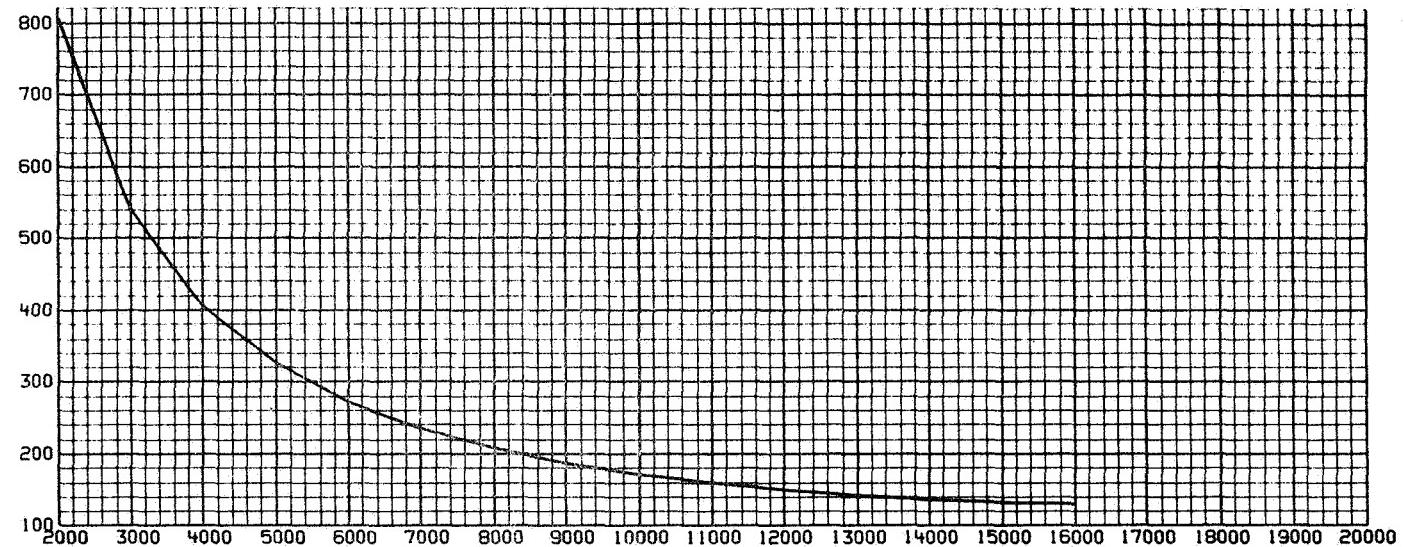


Figure 3-45

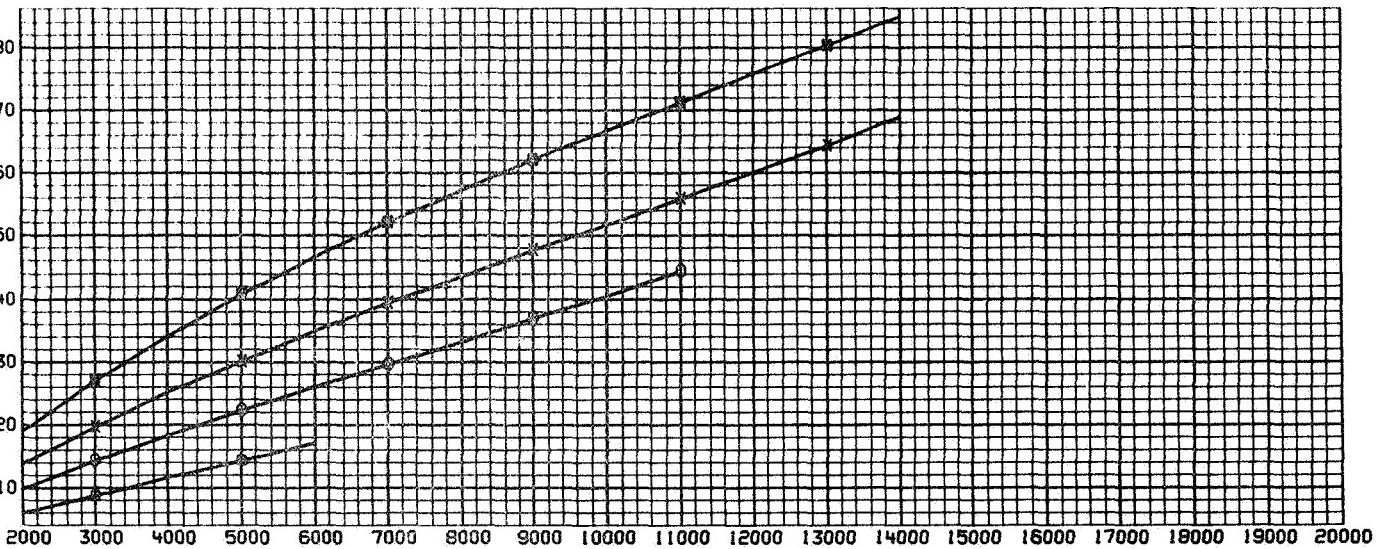
PAYOUT DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT



○ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. □ = FIXED IGNITION 65000 LBS.



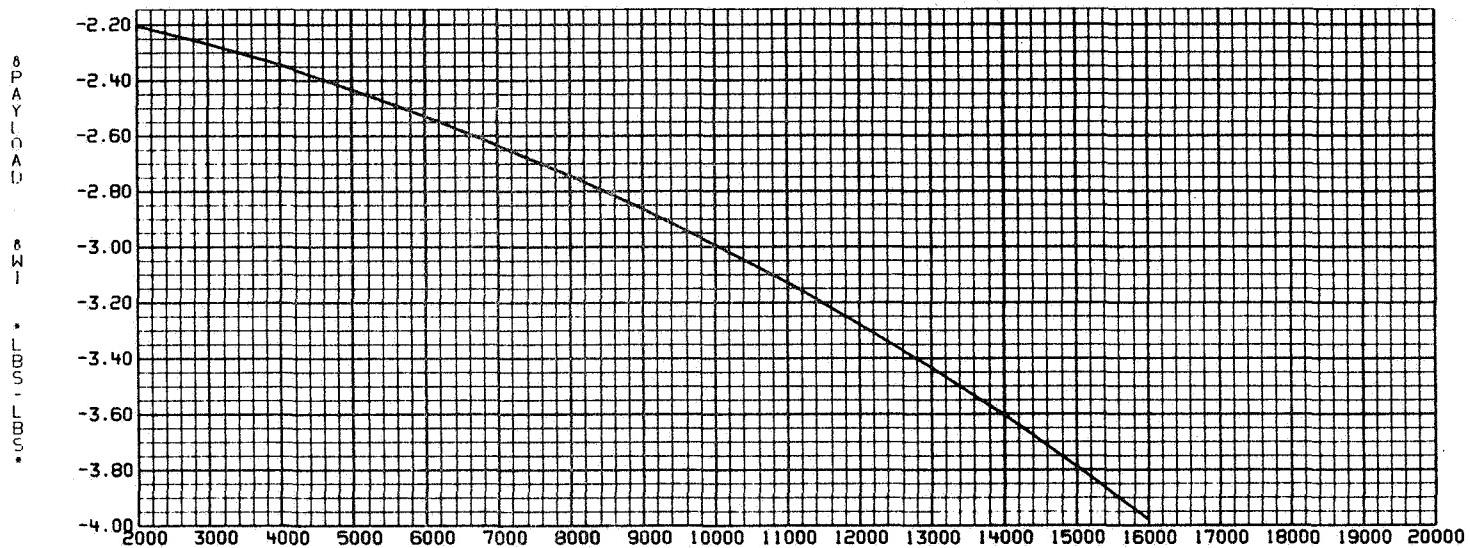
ON ORBIT VELOCITY *FT/SEC*

Figure 3-46

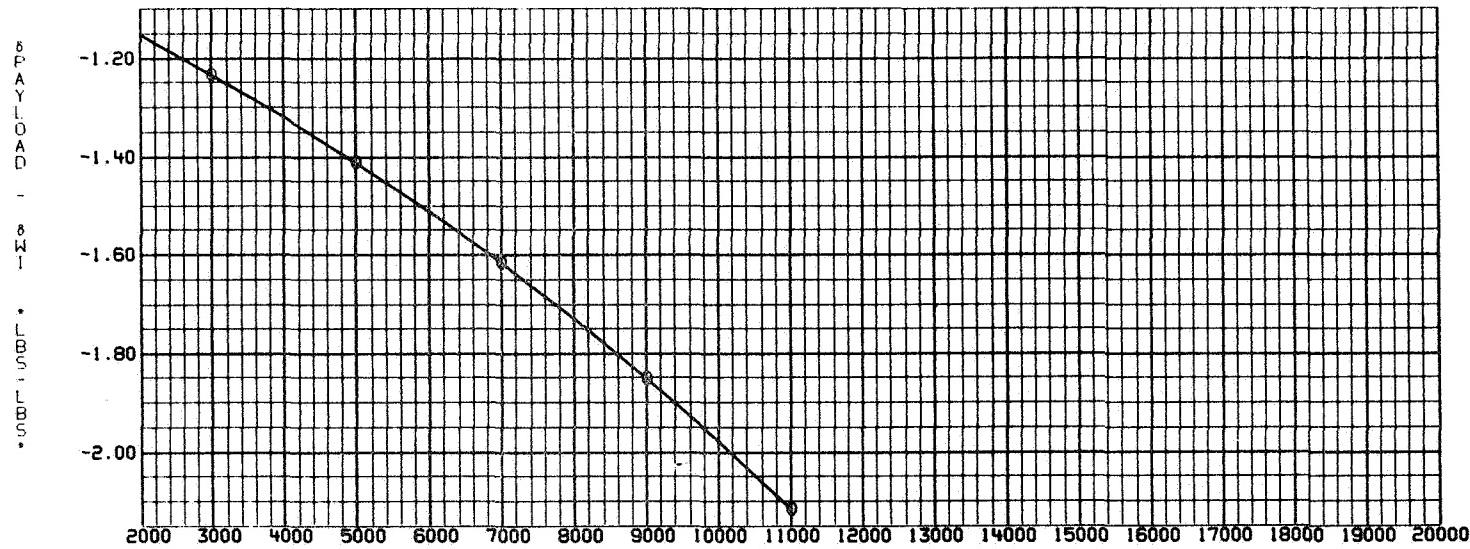
PAYOUT DELIVERED

EXPENDABLE PAYL • REUSEABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



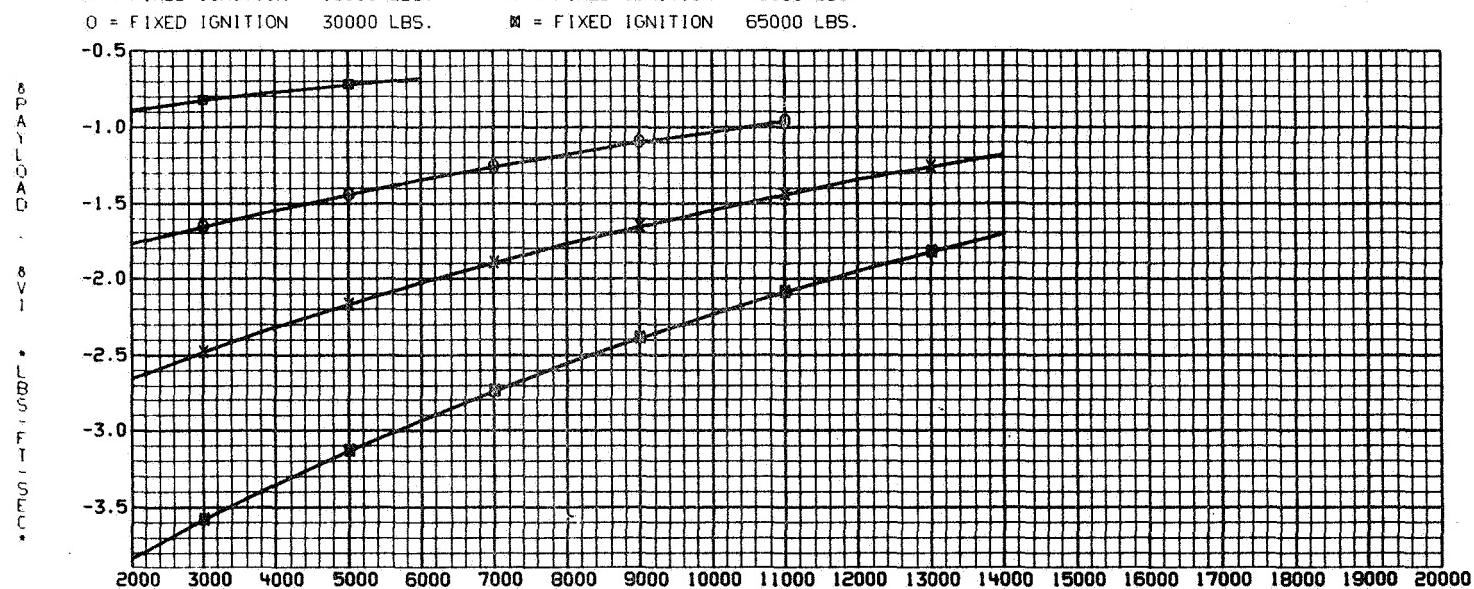
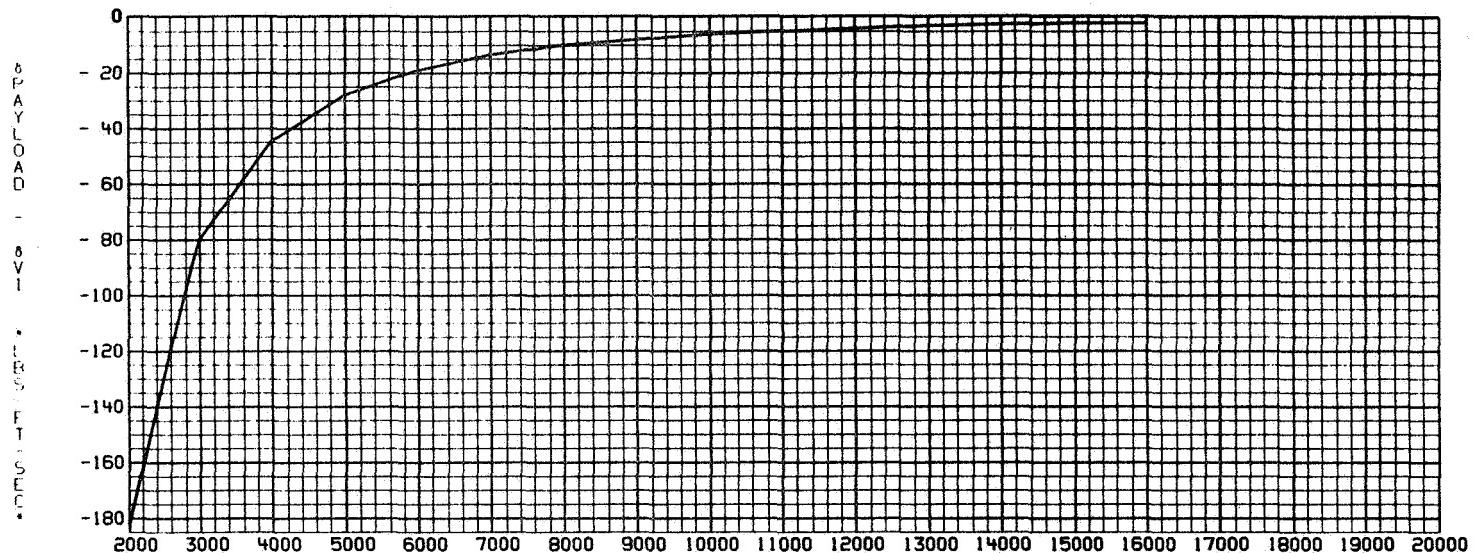
ON ORBIT VELOCITY *FT/SEC*

Figure 3-47

PAYOUT DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

5015B LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-48

PAYOUT DELIVERED
5015B LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE P/L • REUSEABLE TUG

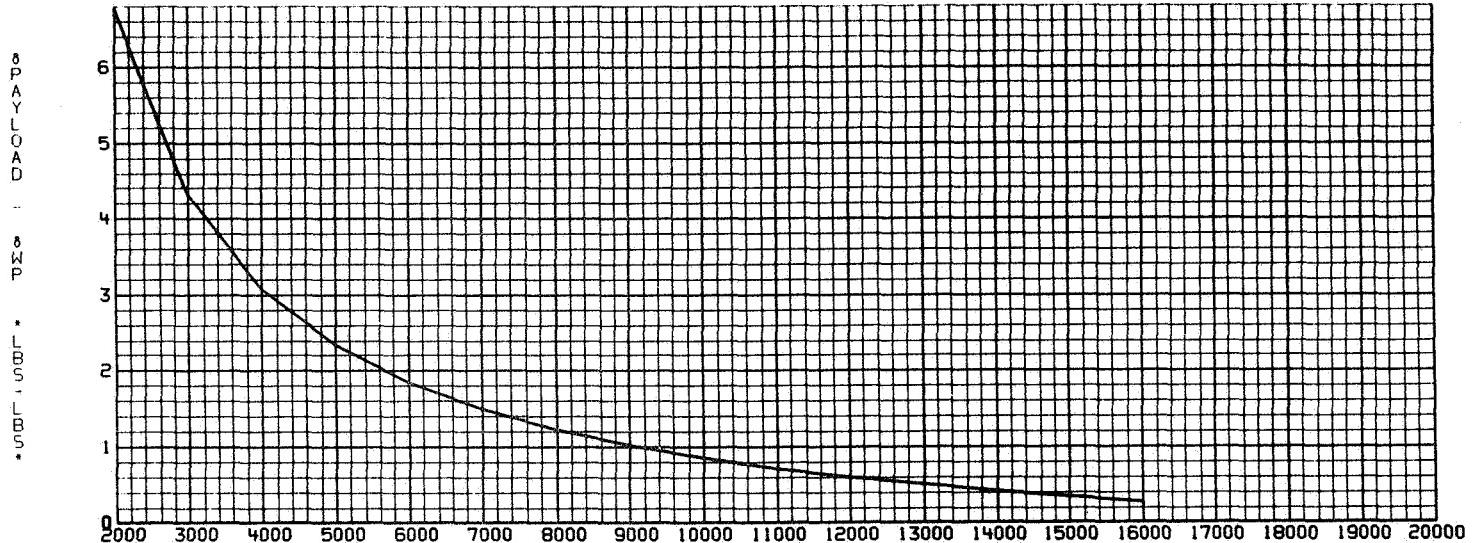
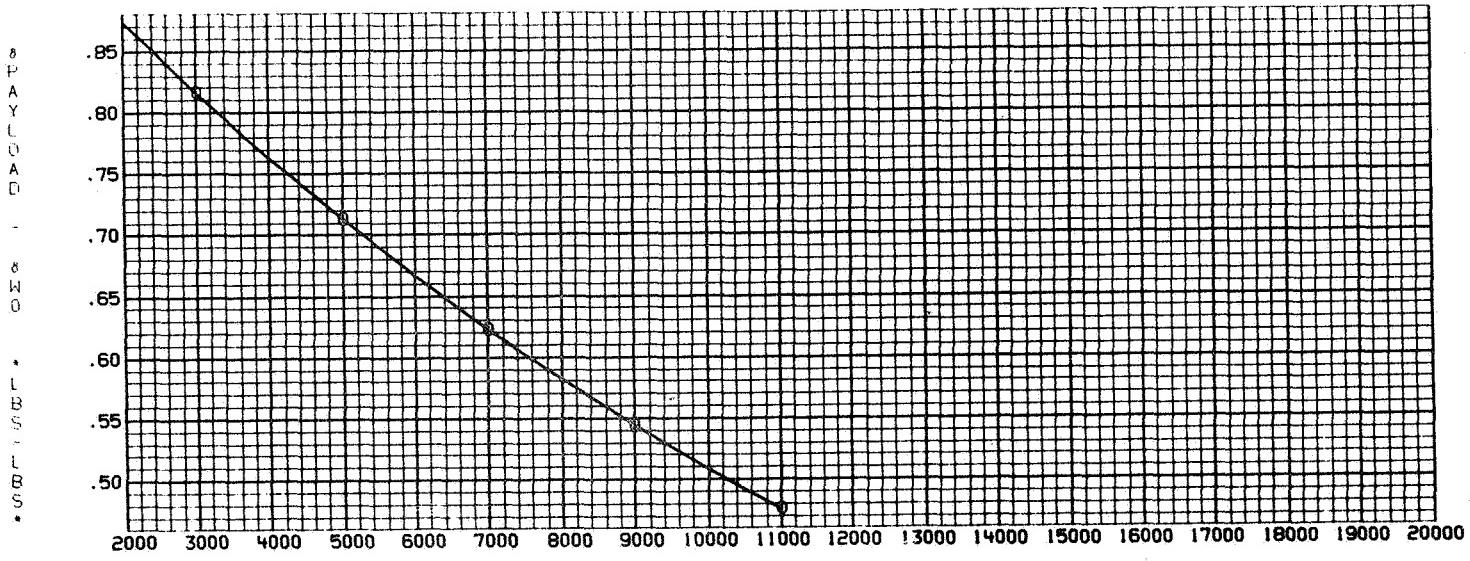


Figure 3-49

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-50

3-45

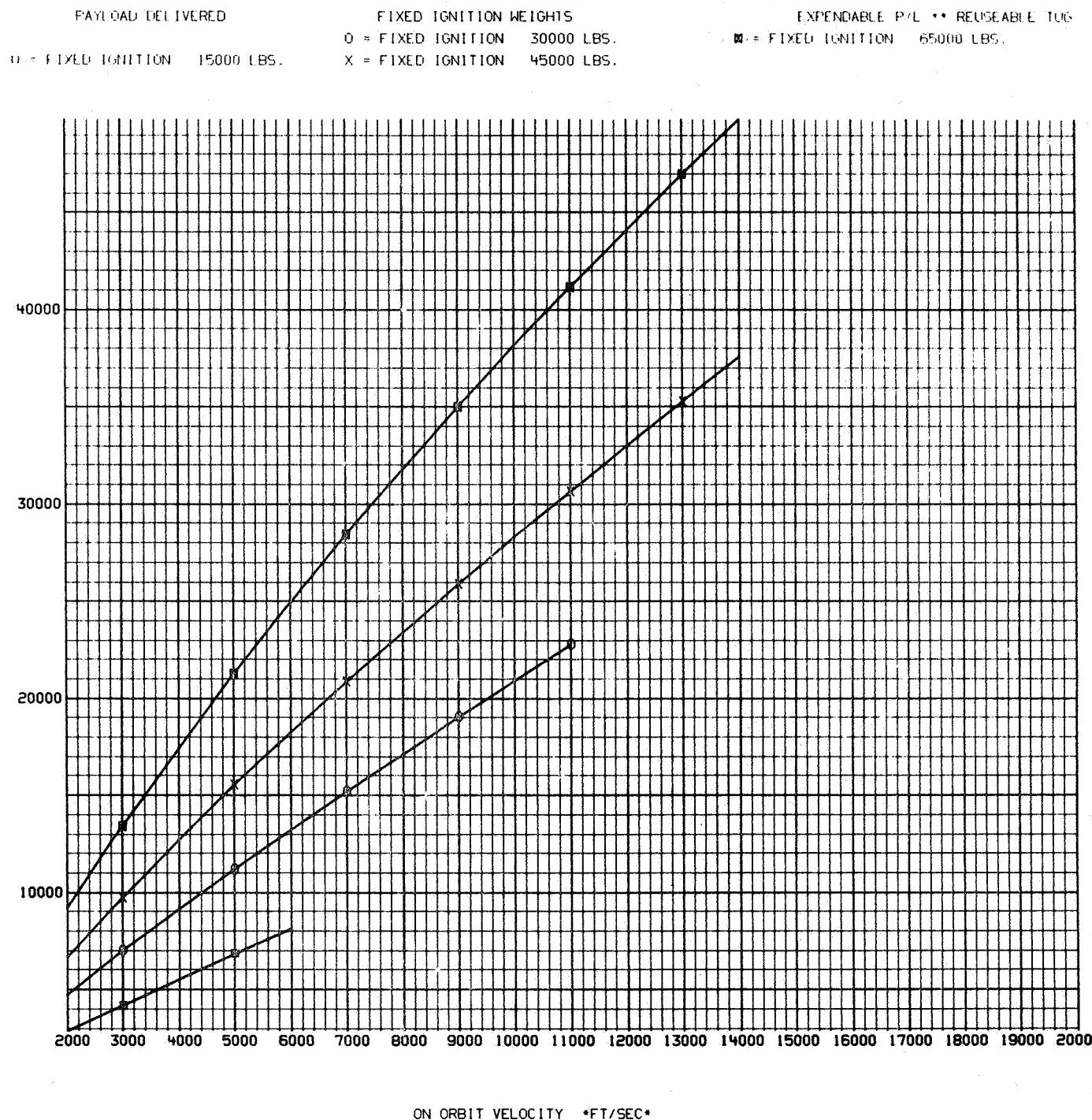


Figure 3-51

MODE 4

Payload Delivered
- = Fixed Propellant 50158 LBS.
o = Fixed Ignition 15000 LBS.

50158 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
XED IGNITION 65000 LBS.

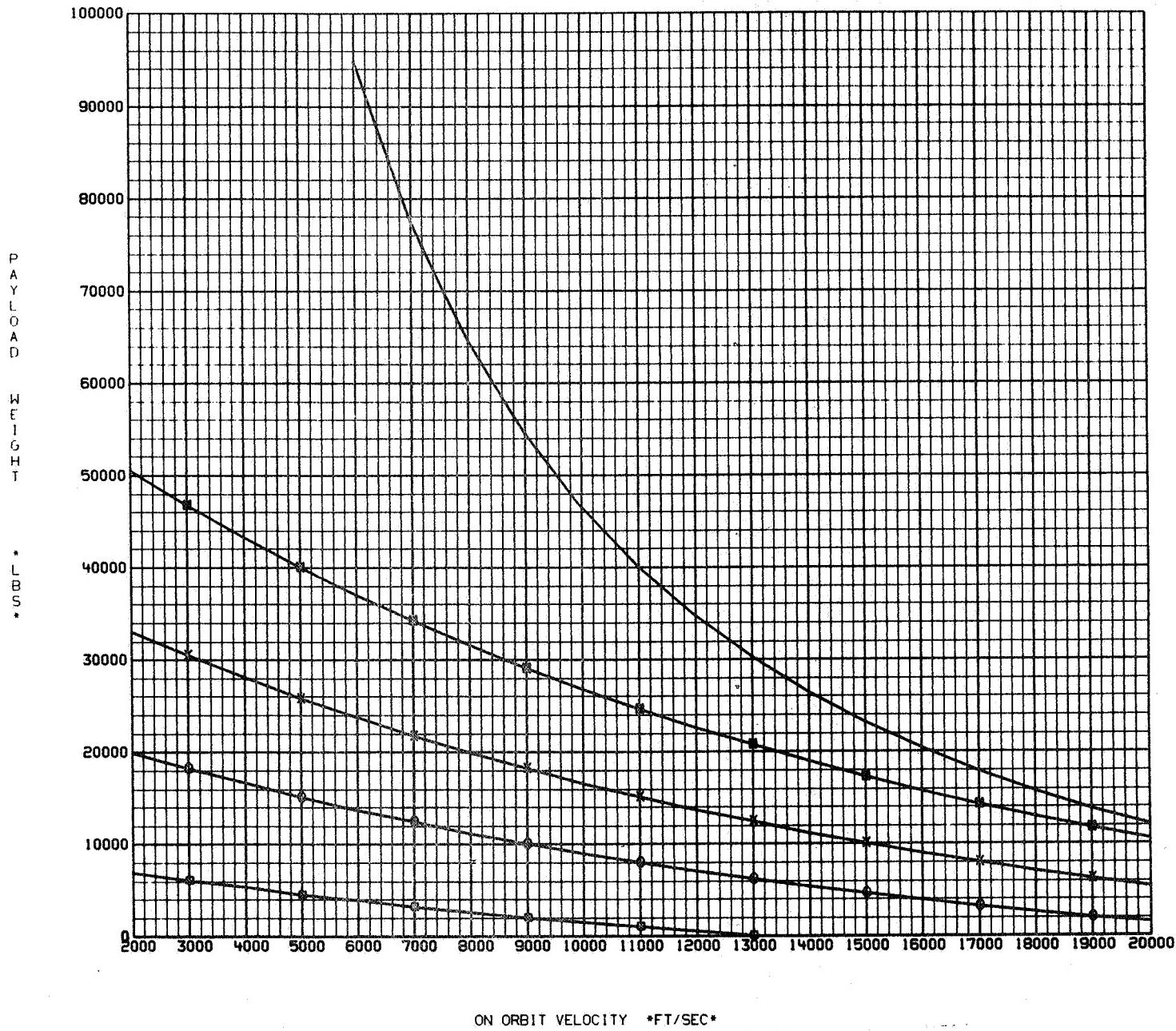
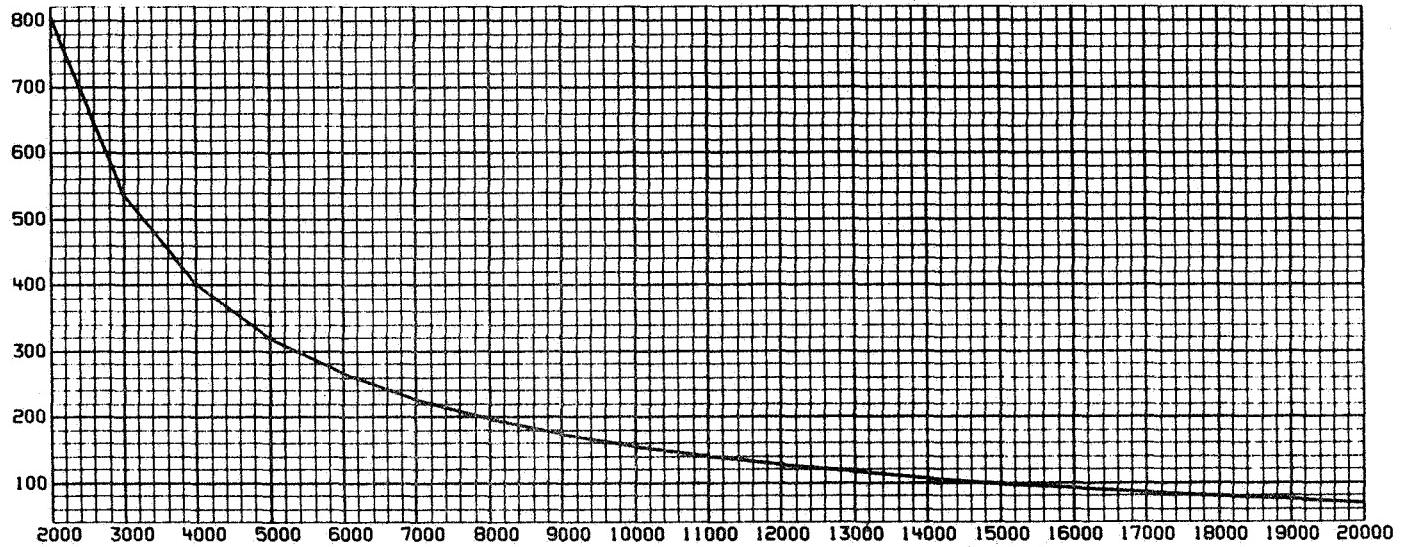


Figure 3-52

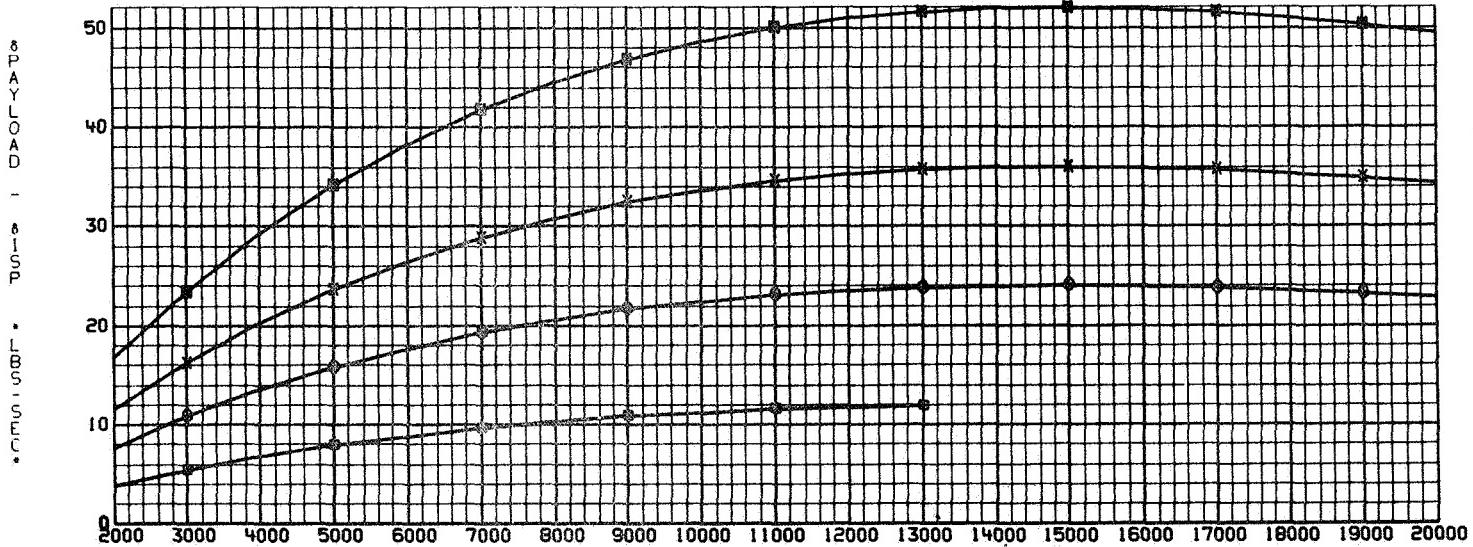
PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



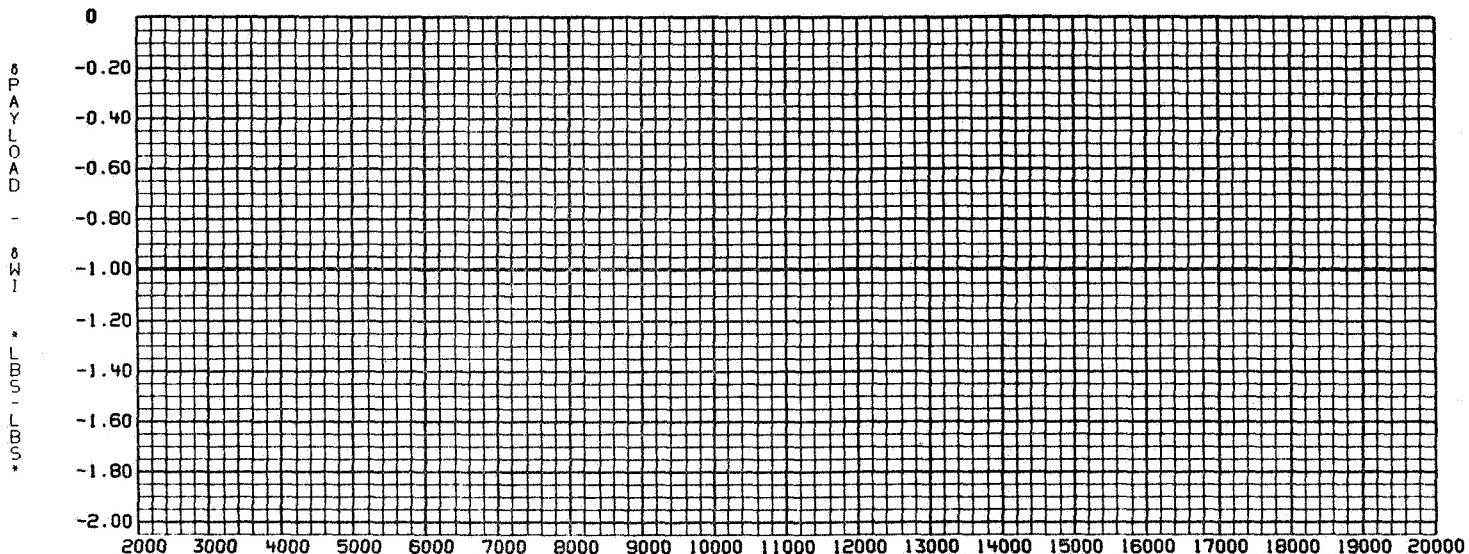
ON ORBIT VELOCITY *FT/SEC*

Figure 3-53

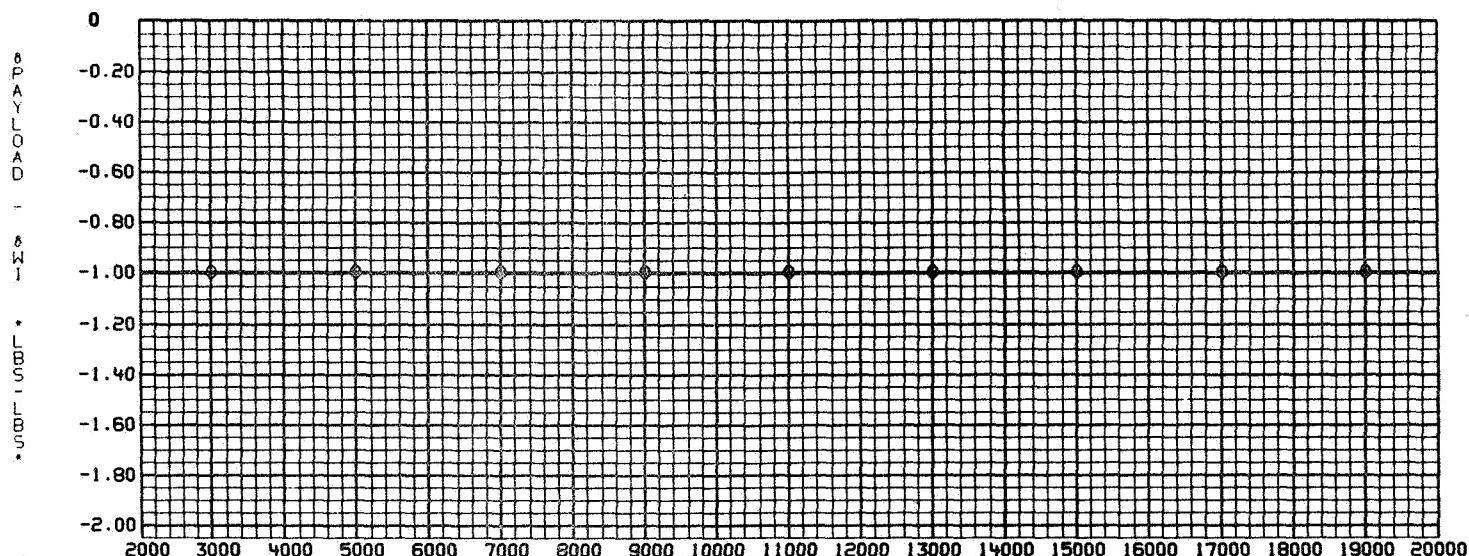
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-54

PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT

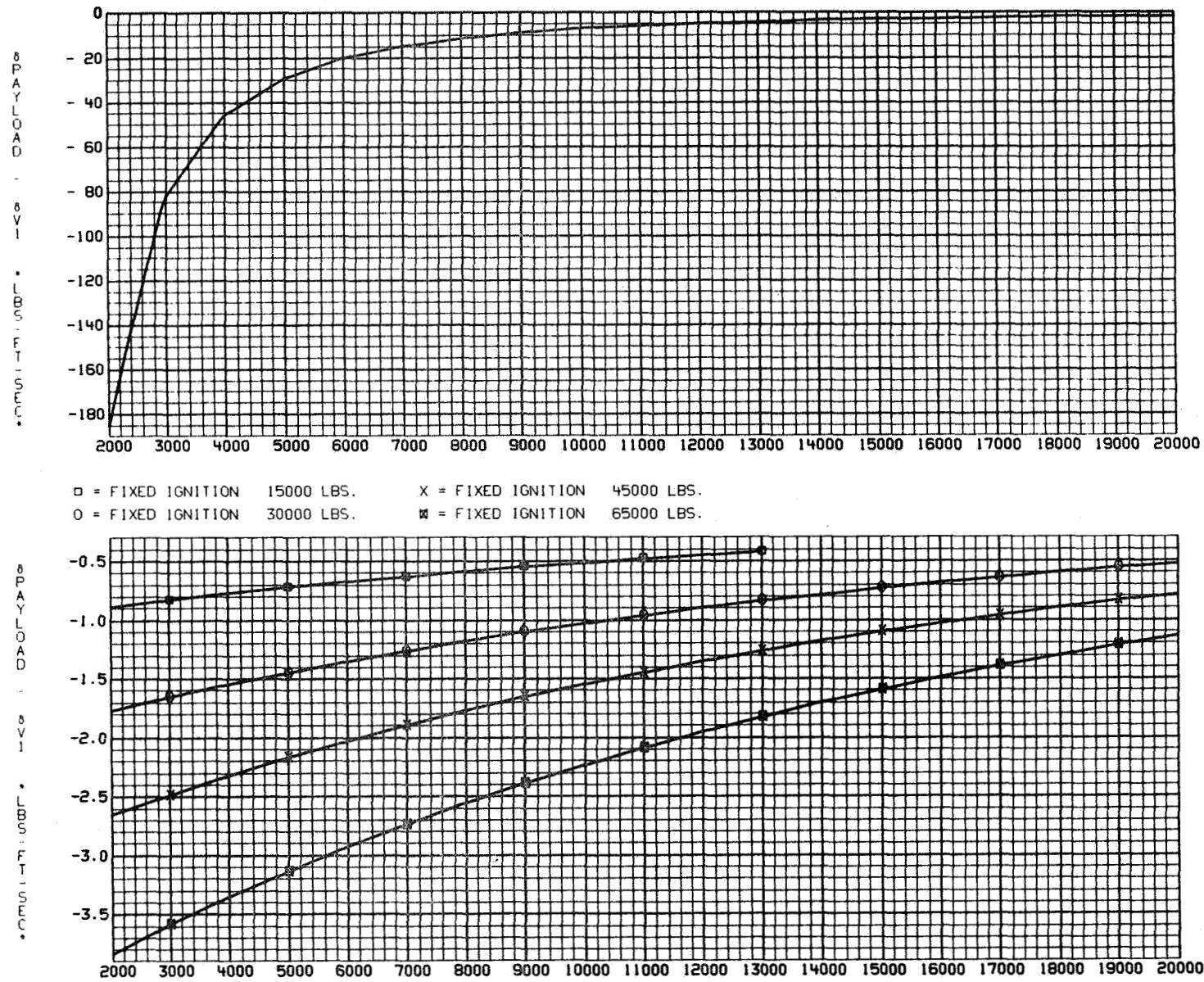


Figure 3-55

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT

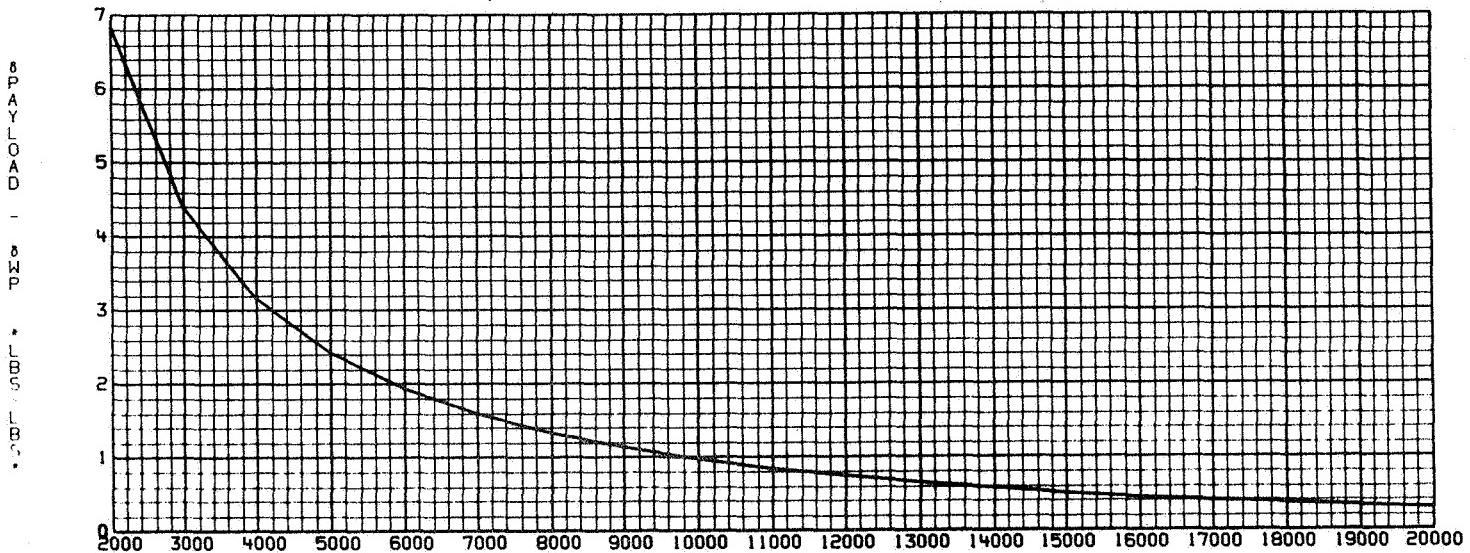
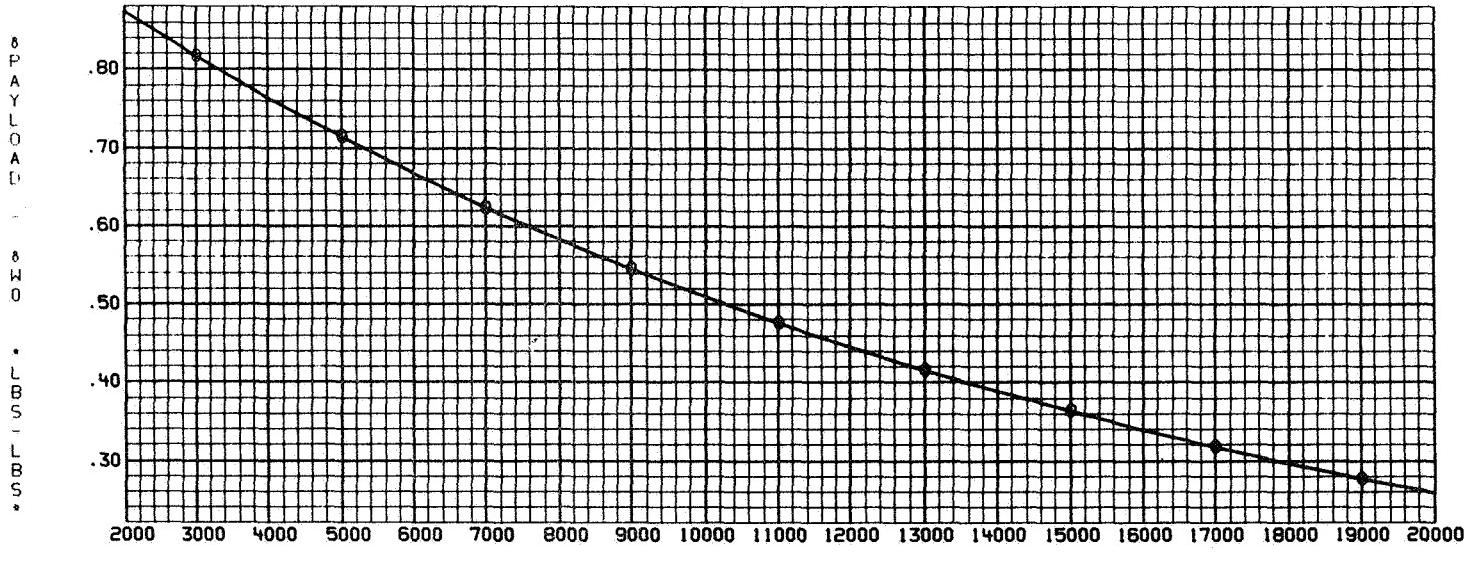


Figure 3-56

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-57

= FIXED IGNITION 15000 LBS.

FIXED IGNITION WEIGHTS
0 = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P.L.
■ = FINED IGNITION 65000 LBS.

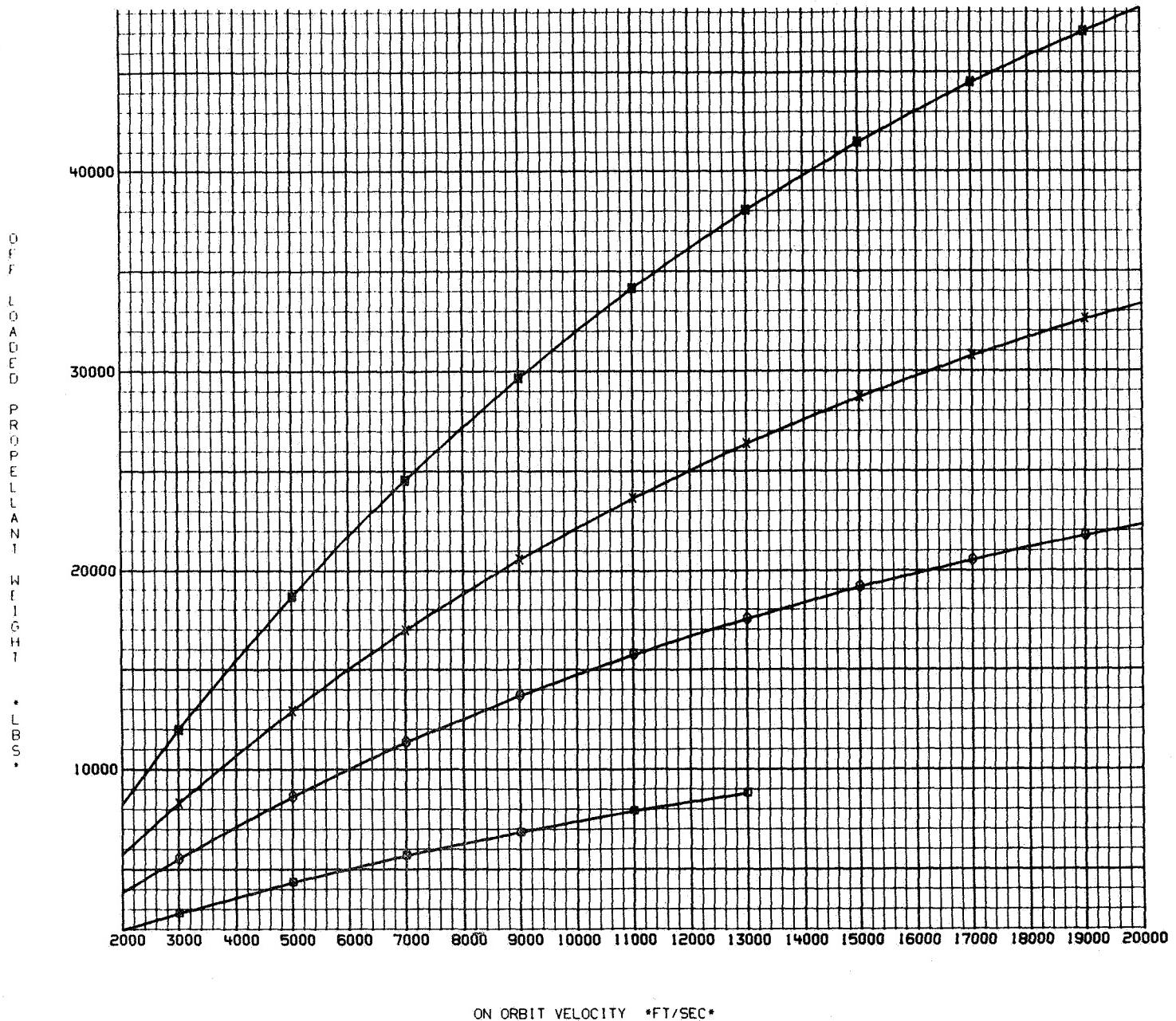


Figure 3-58

MODE 1

PAYLOAD DELIVERED
• = FIXED PROPELLANT 36295 LBS.
□ = FIXED IGNITION 15000 LBS.

36295 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

ROUND TRIPPED P/L CAPABILITY
■ = FIXED IGNITION 65000 LBS.

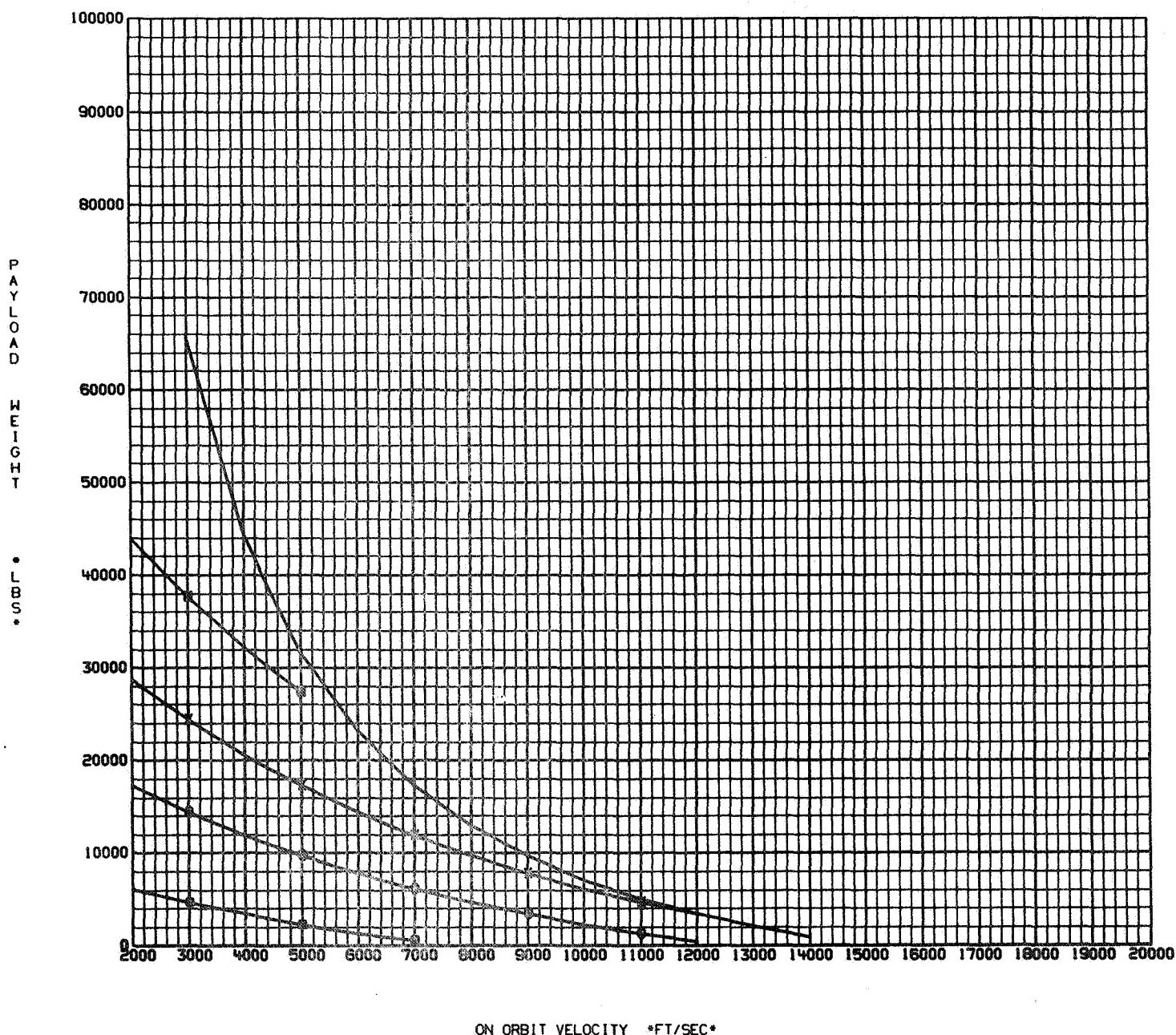


Figure 3-59

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

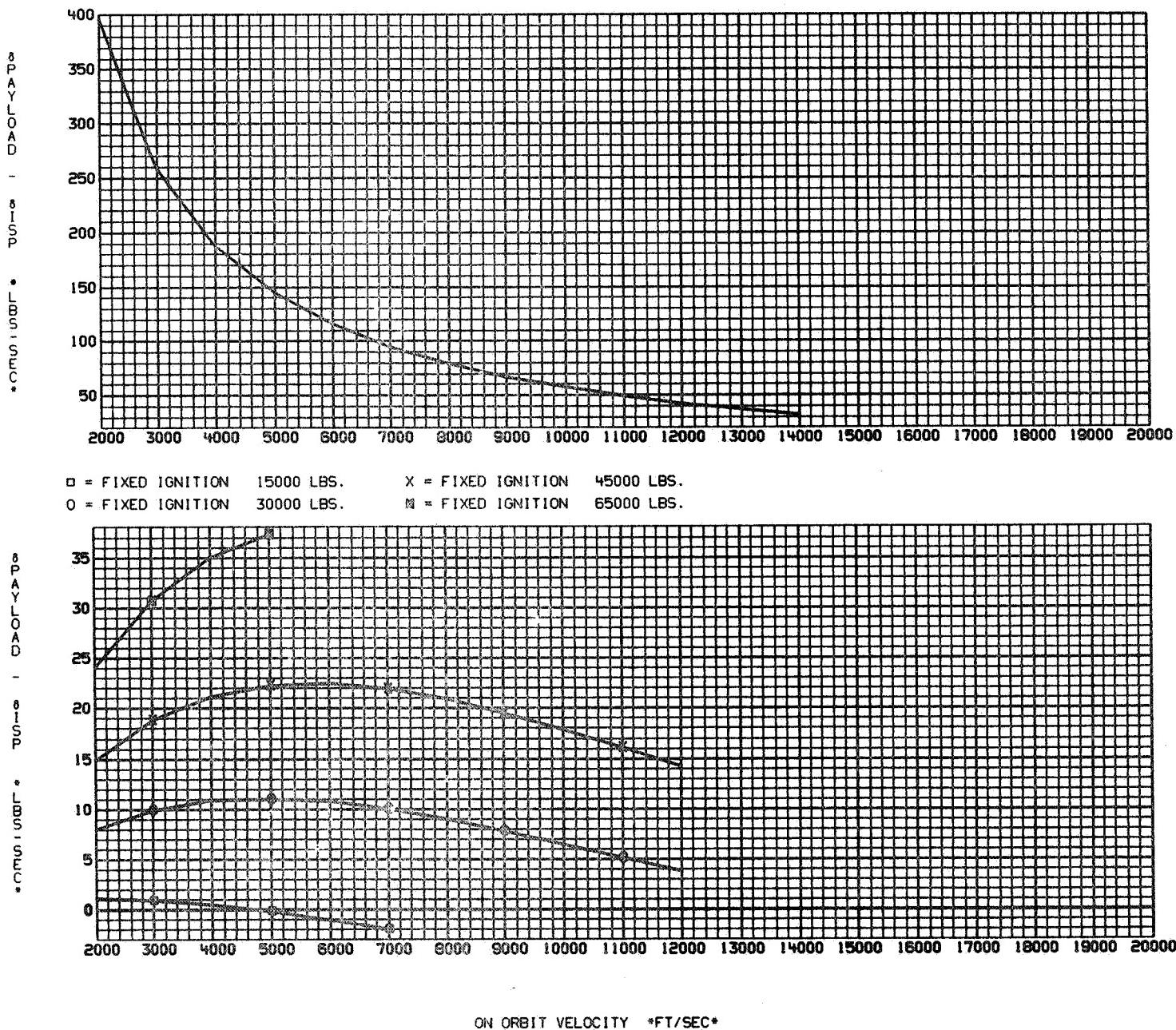
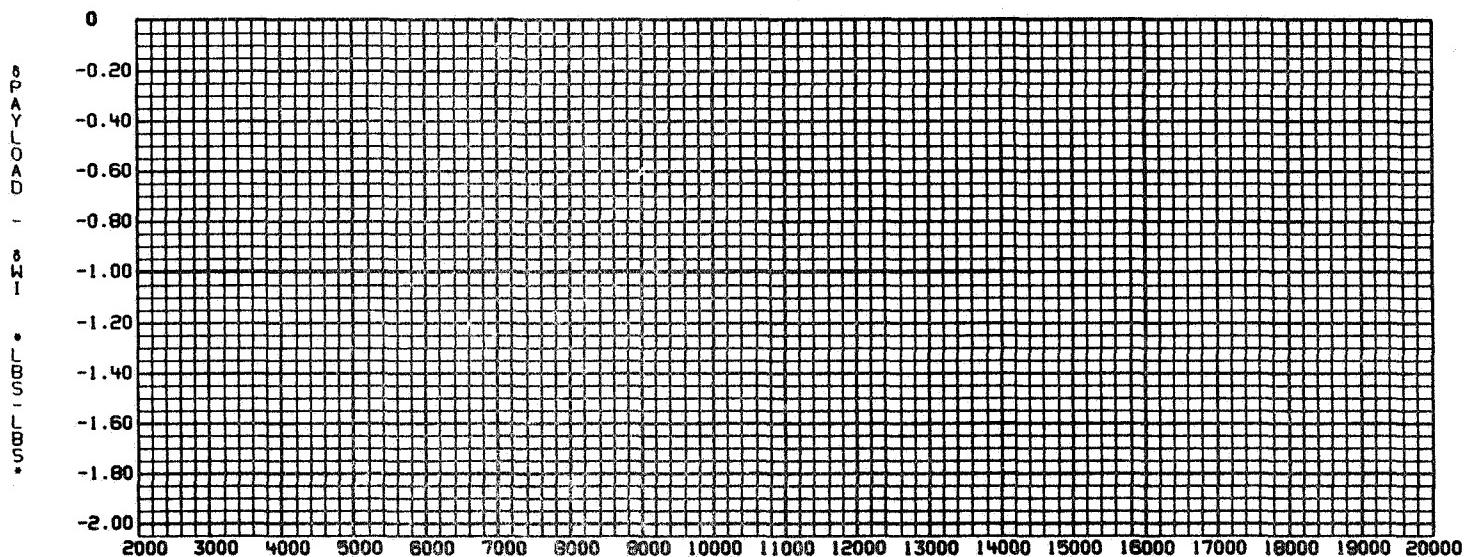


Figure 3-60

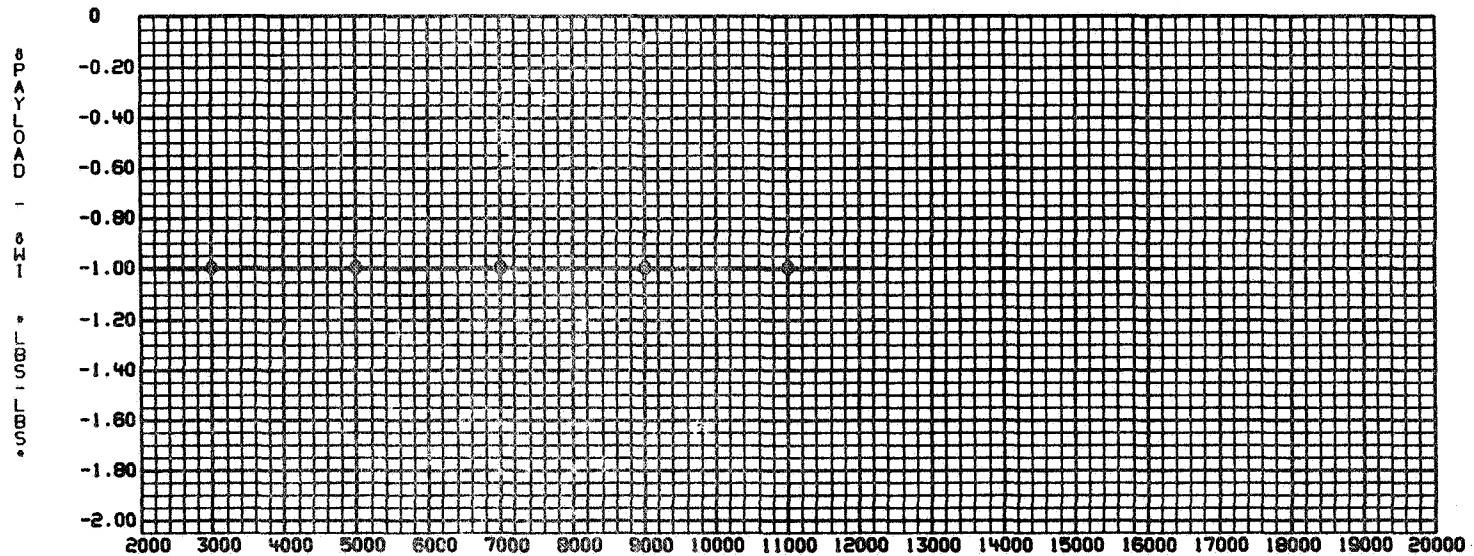
PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



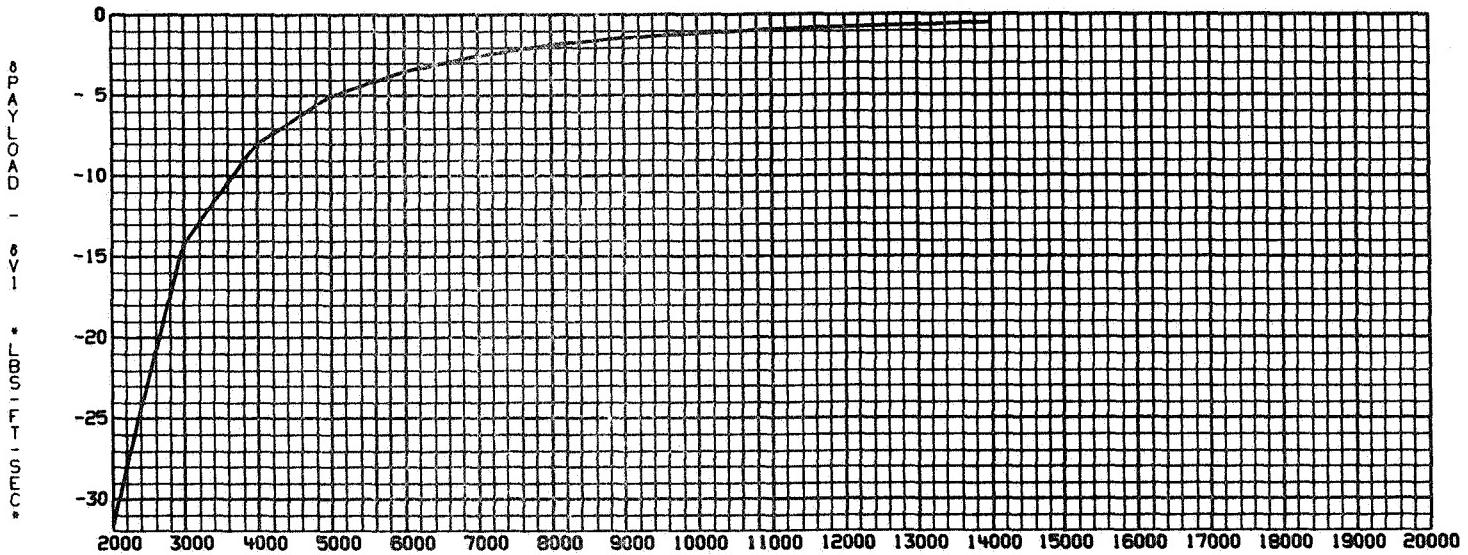
ON ORBIT VELOCITY *FT/SEC*

Figure 3-61

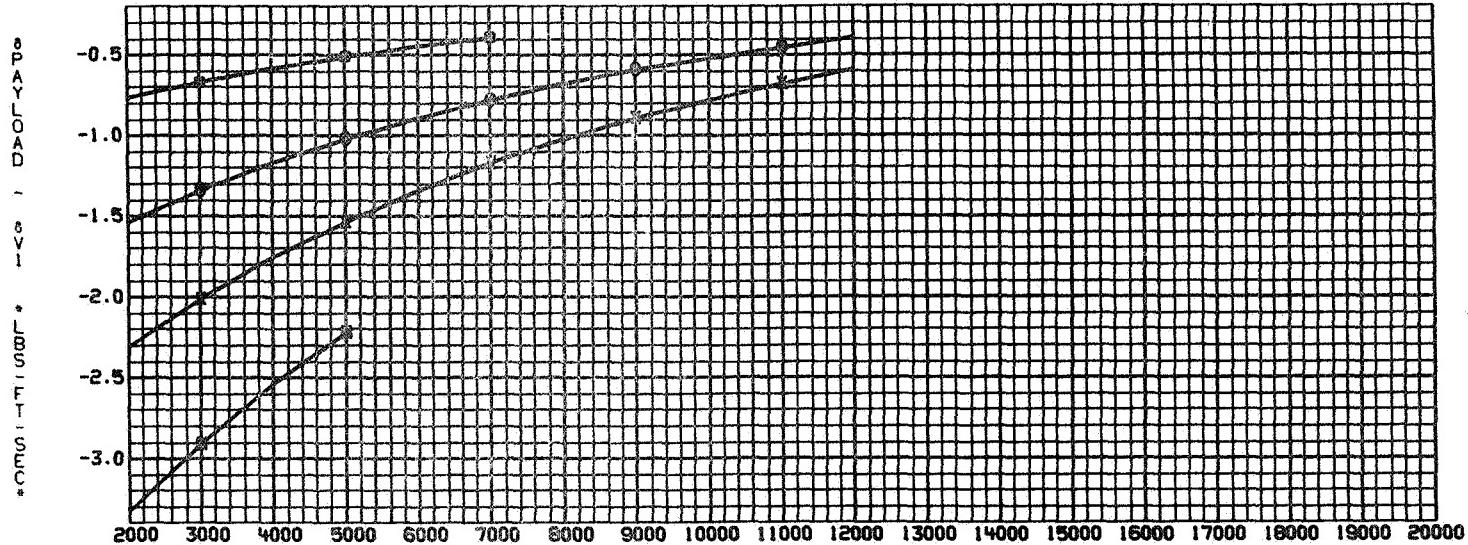
PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ◇ = FIXED IGNITION 65000 LBS.



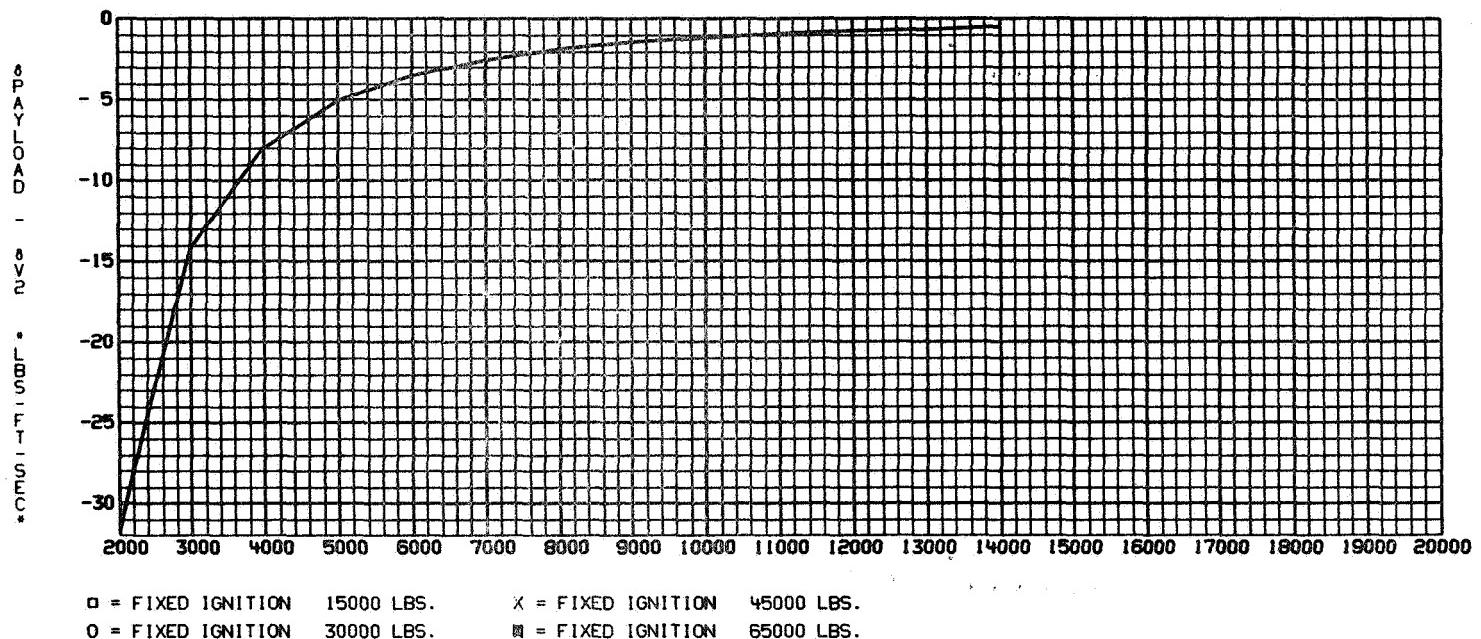
ON ORBIT VELOCITY *FT/SEC*

Figure 3-62

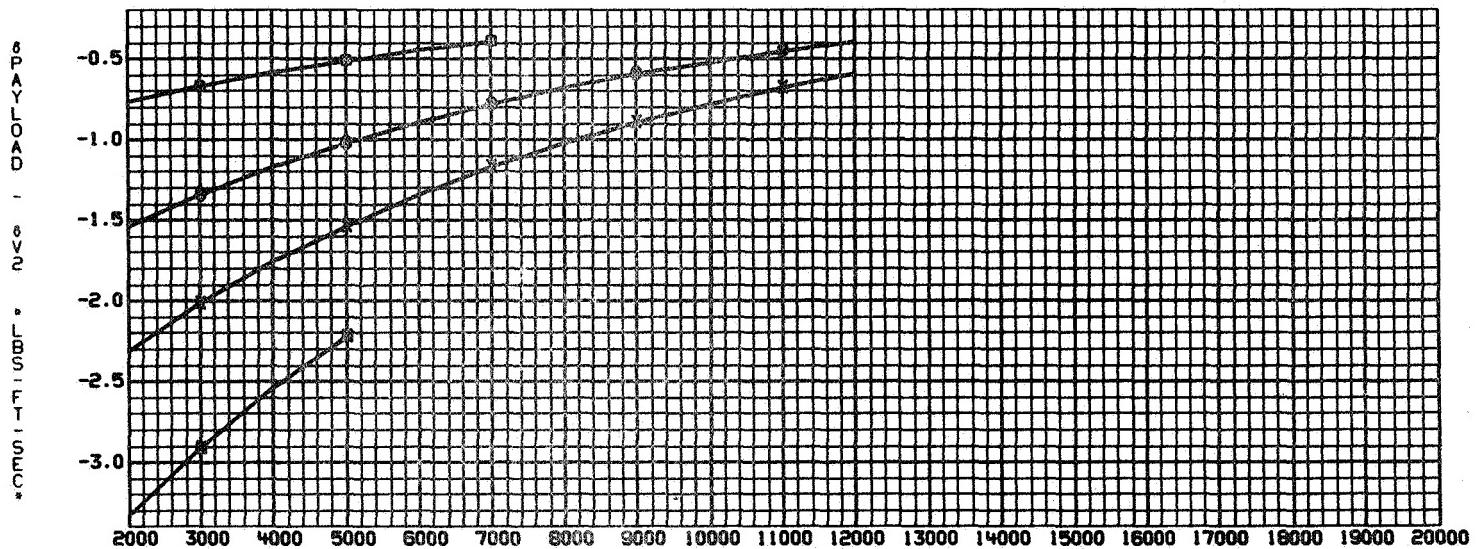
PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. × = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-63

PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

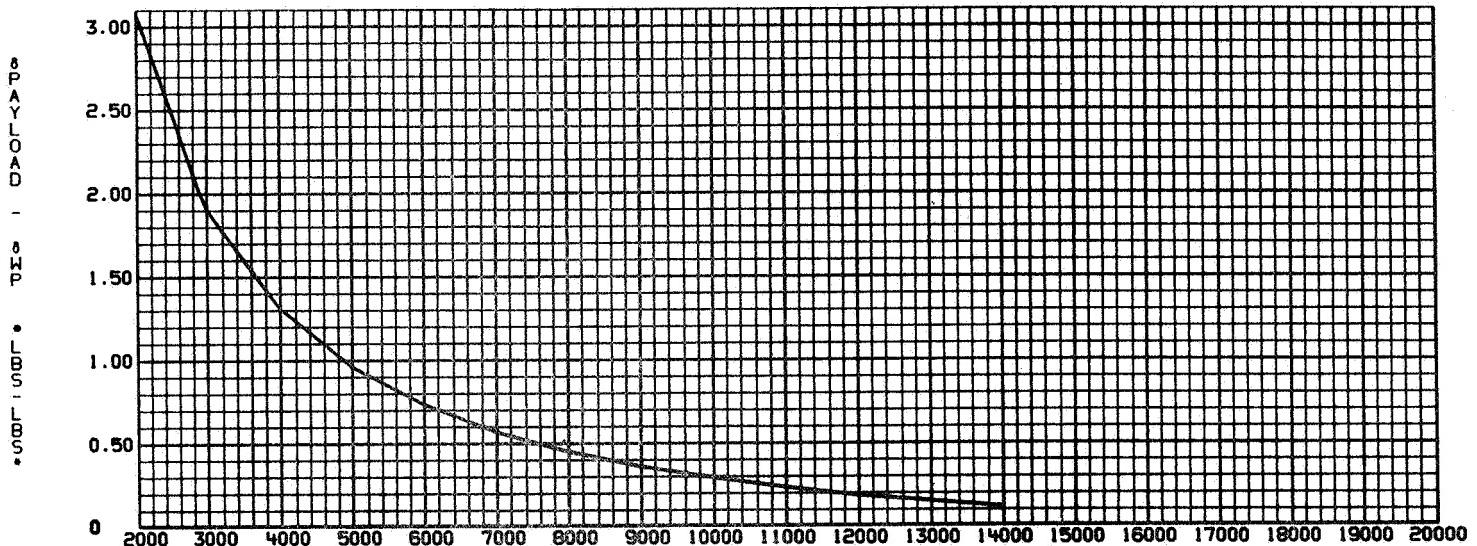
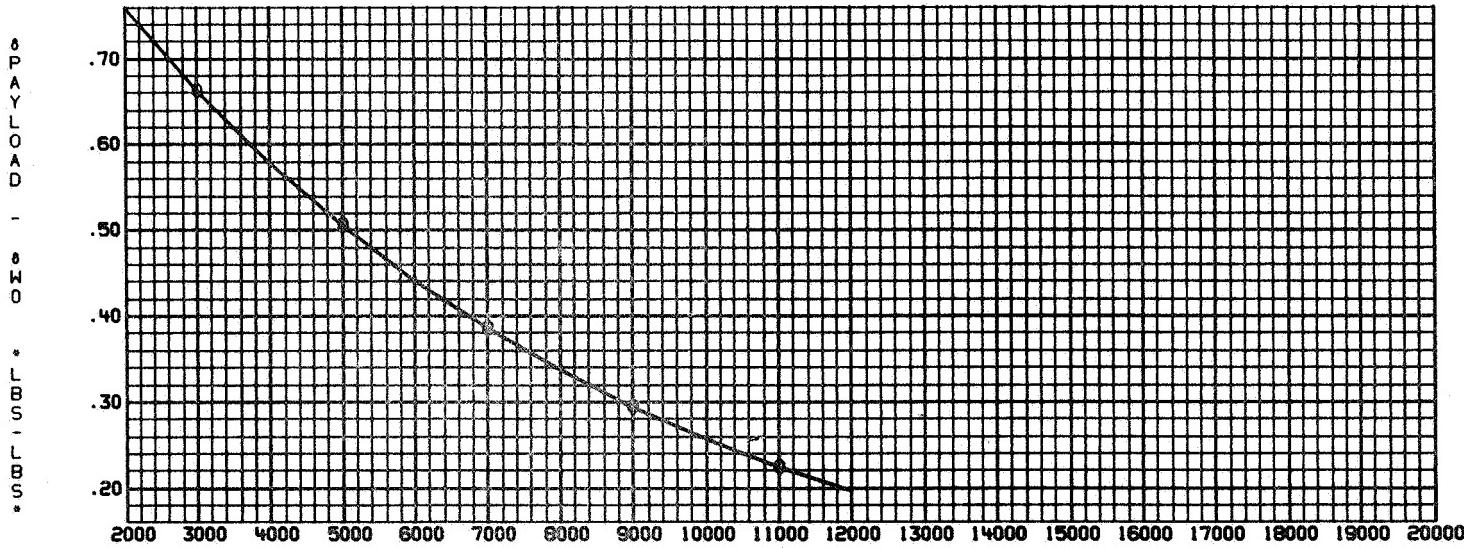


Figure 3-64

ALL FIXED IGNITION WEIGHTS



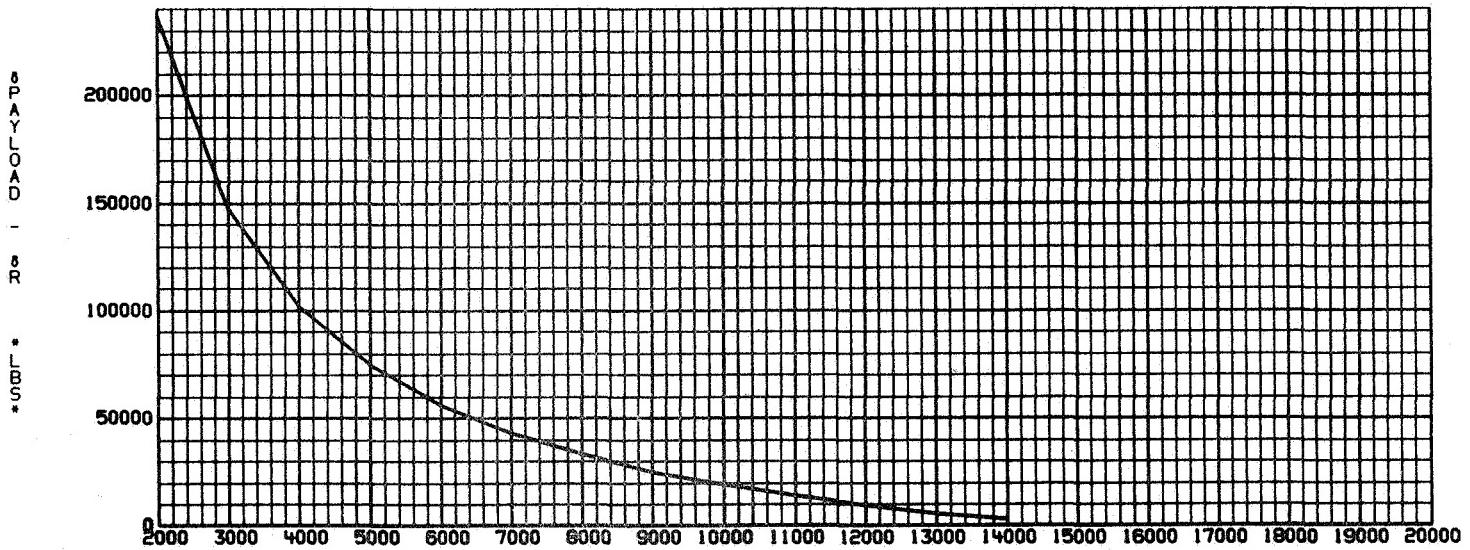
ON ORBIT VELOCITY *FT/SEC*

Figure 3-65

Payload Delivered

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



D = FIXED IGNITION 15000 LBS. **X = FIXED IGNITION** 45000 LBS.
O = FIXED IGNITION 30000 LBS. **M = FIXED IGNITION** 65000 LBS.

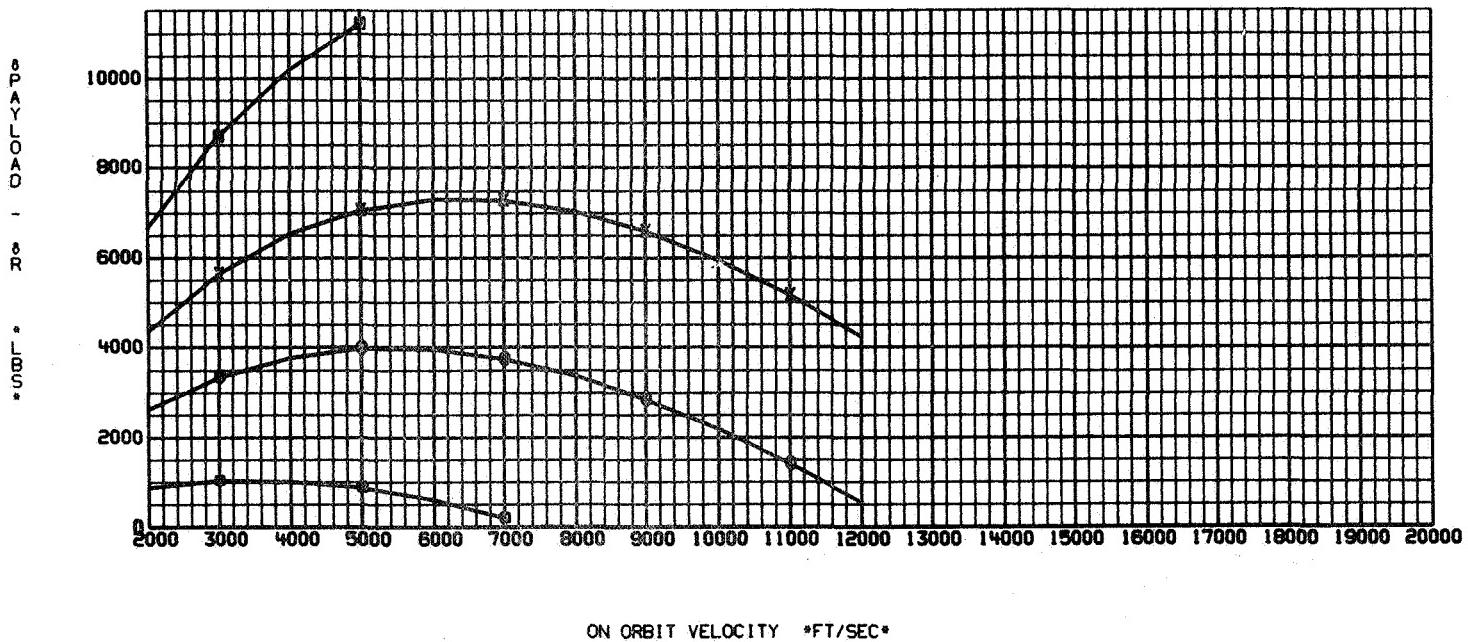


Figure 3-66

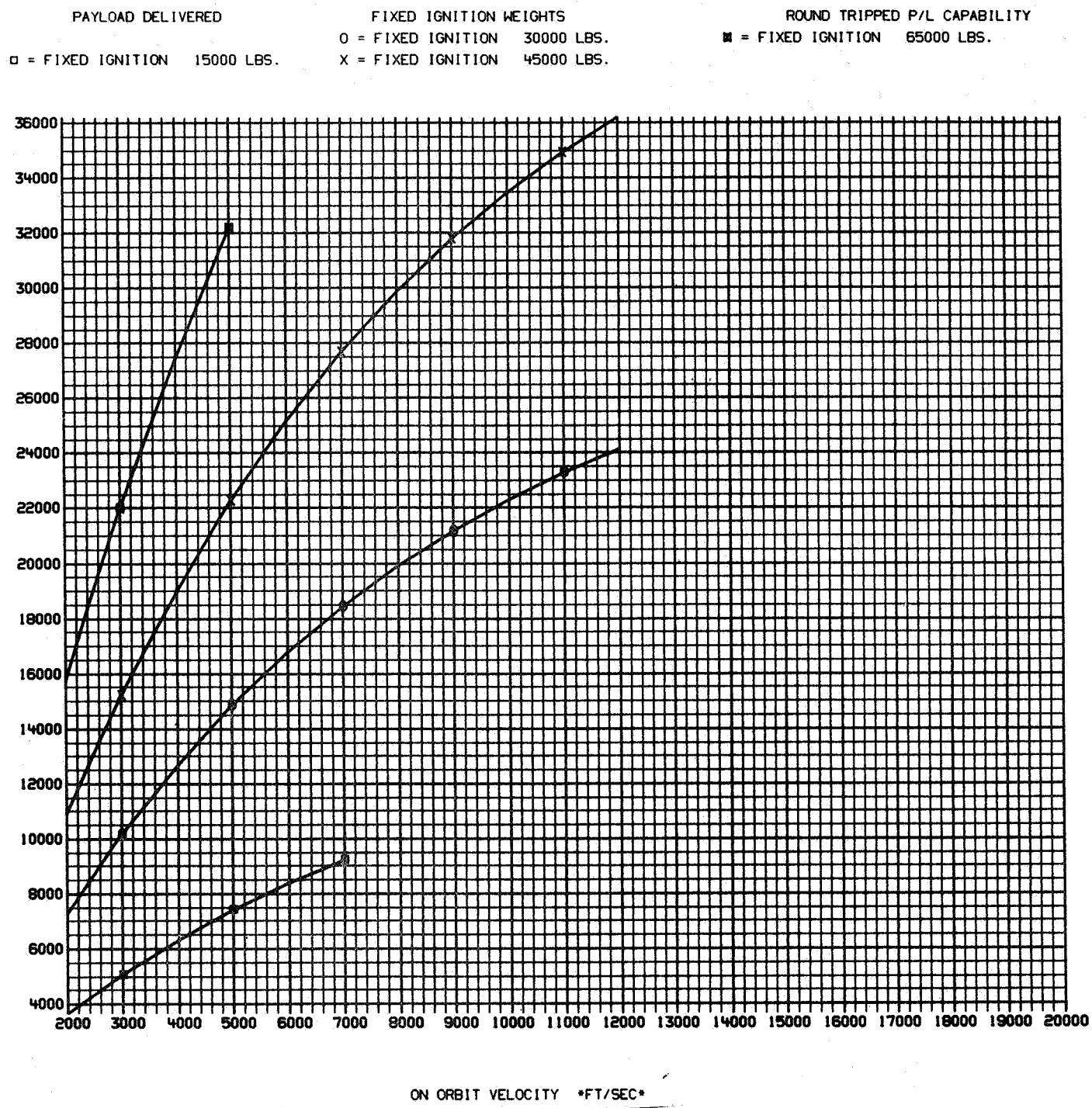


Figure 3-67

MODE 2

PAYOUT RETURNED 36295 LBS. FIXED PROPELLANT WEIGHT TUG - P/L RETRIEVAL CAPABILITY
 • = FIXED PROPELLANT 36295 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
 □ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

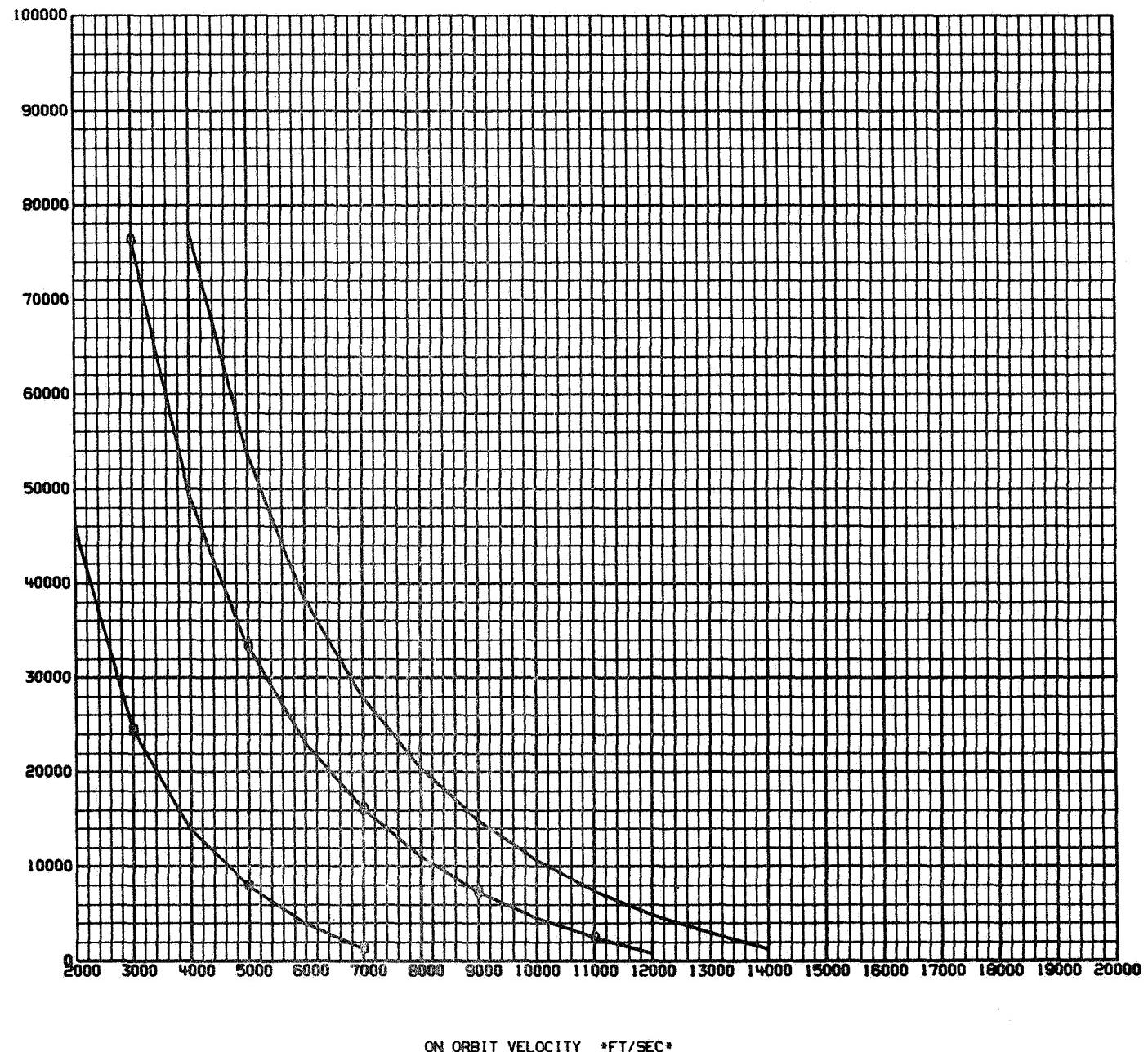


Figure 3-68

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

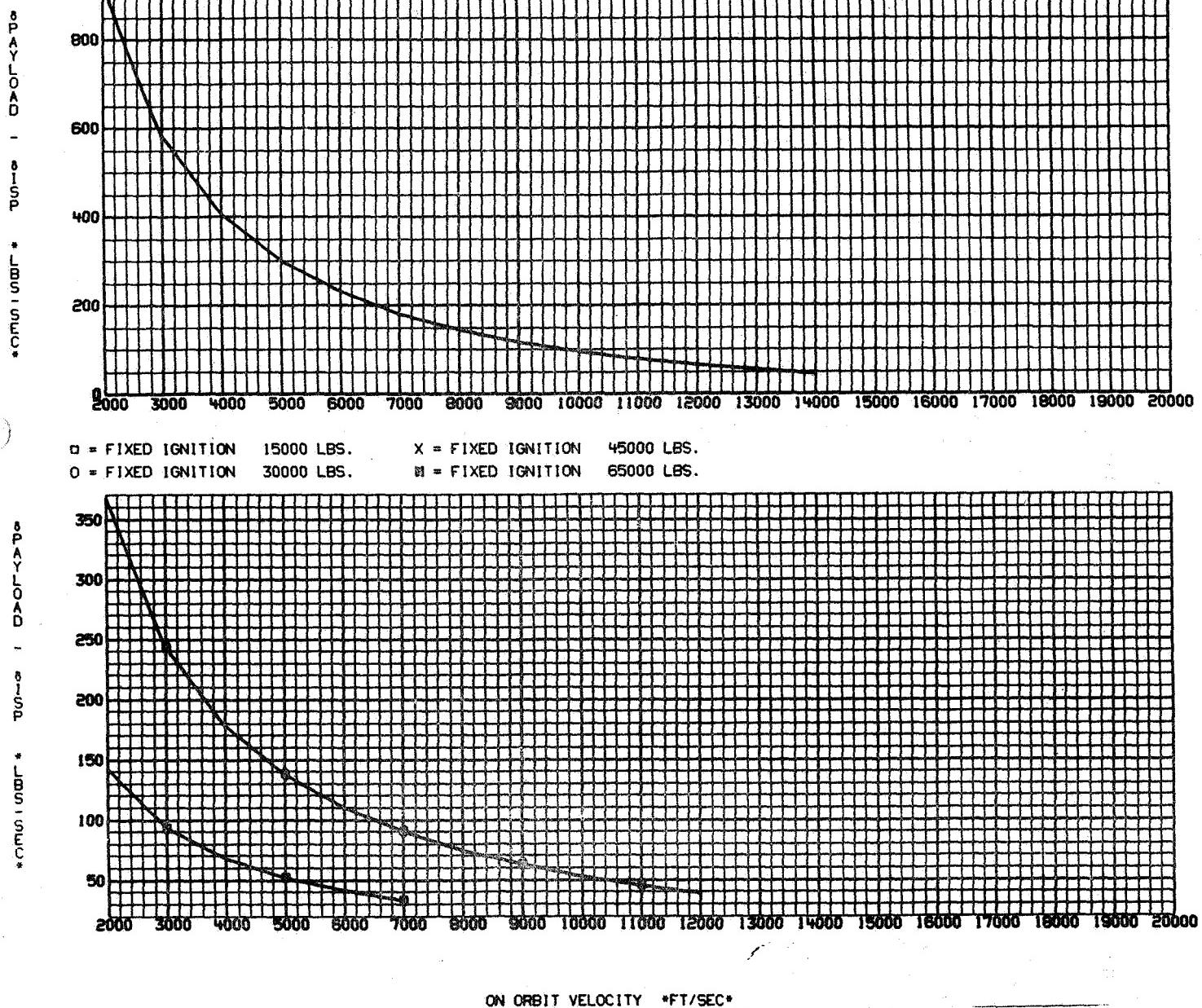
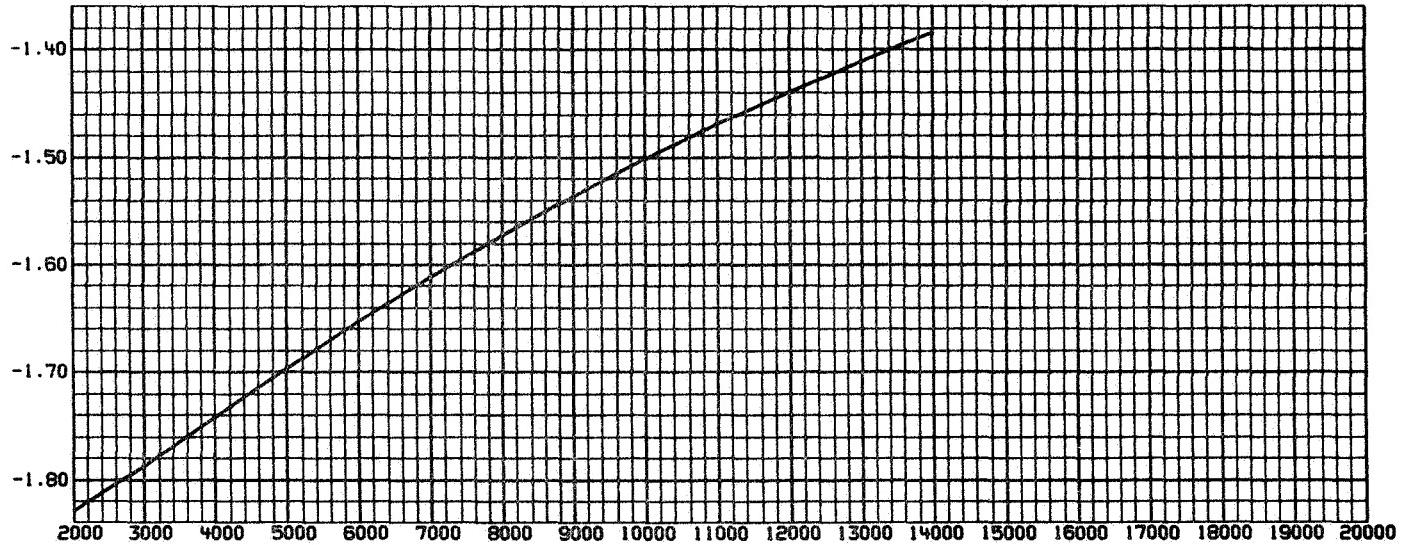


Figure 3-69

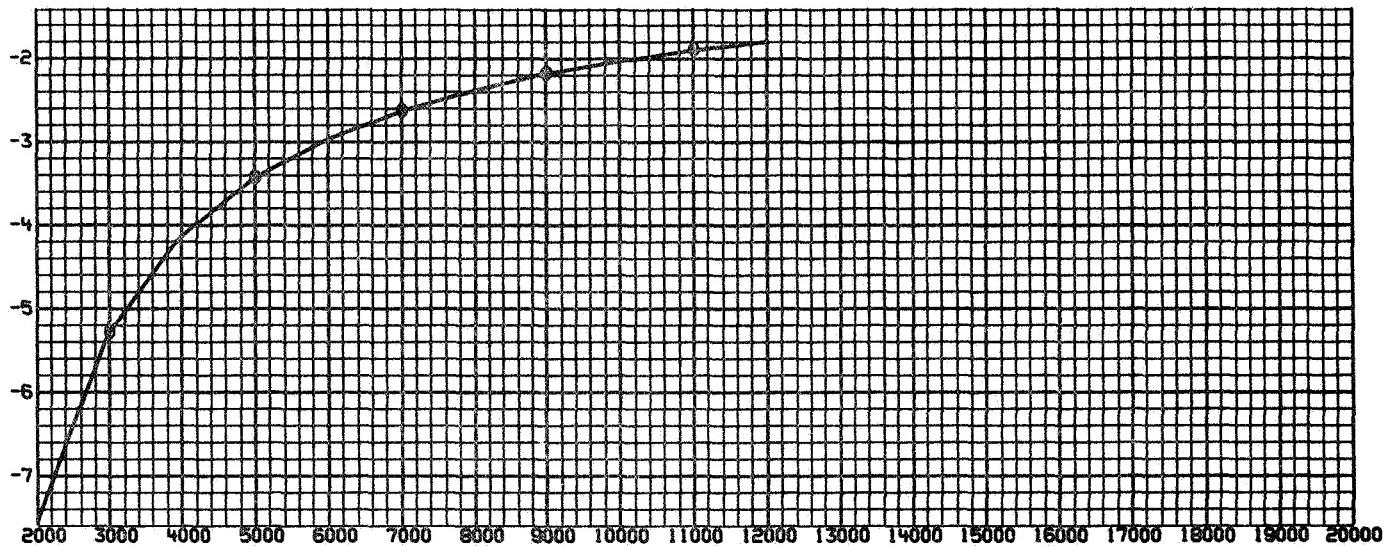
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



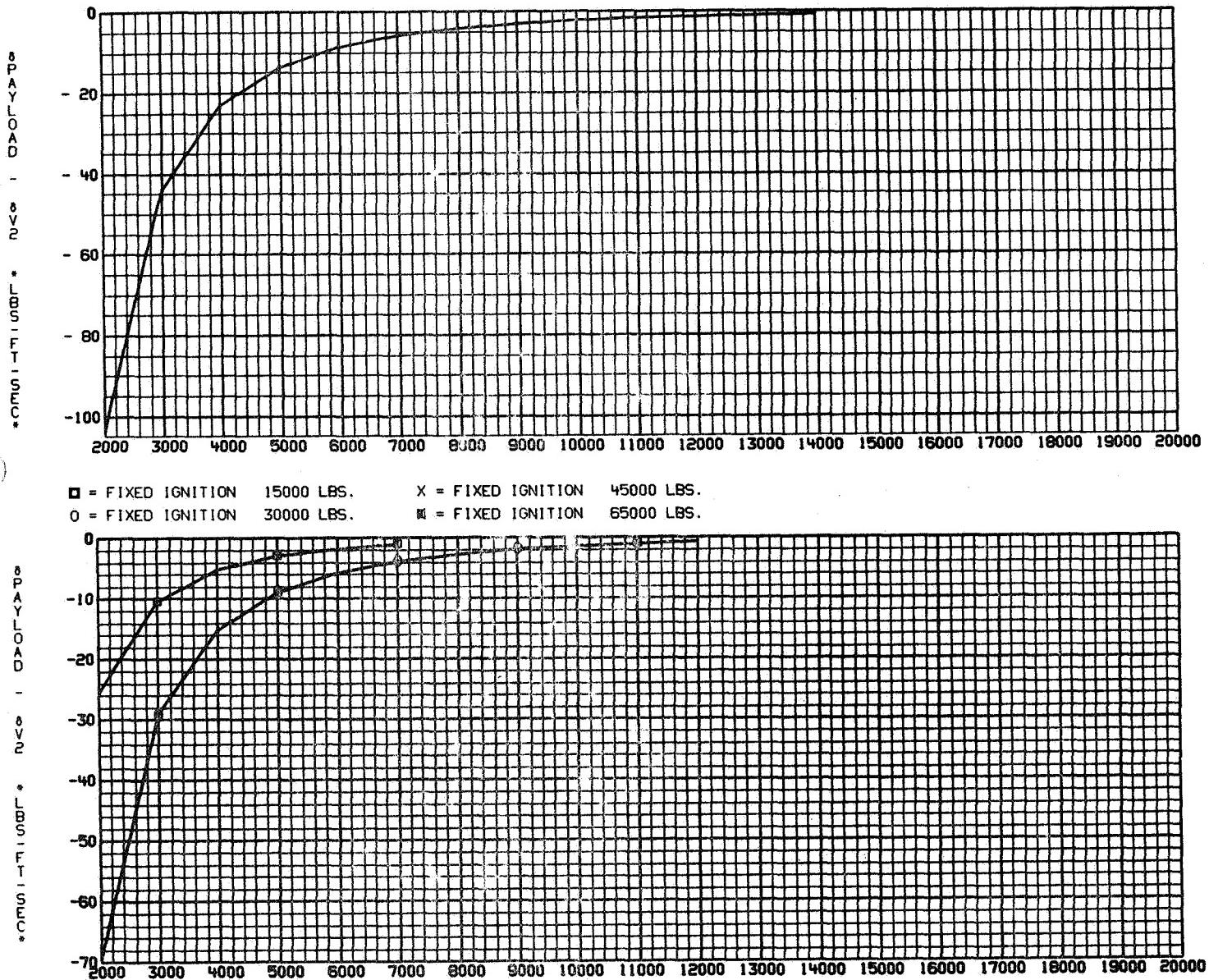
ON ORBIT VELOCITY *FT/SEC*

Figure 3-70

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-71

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

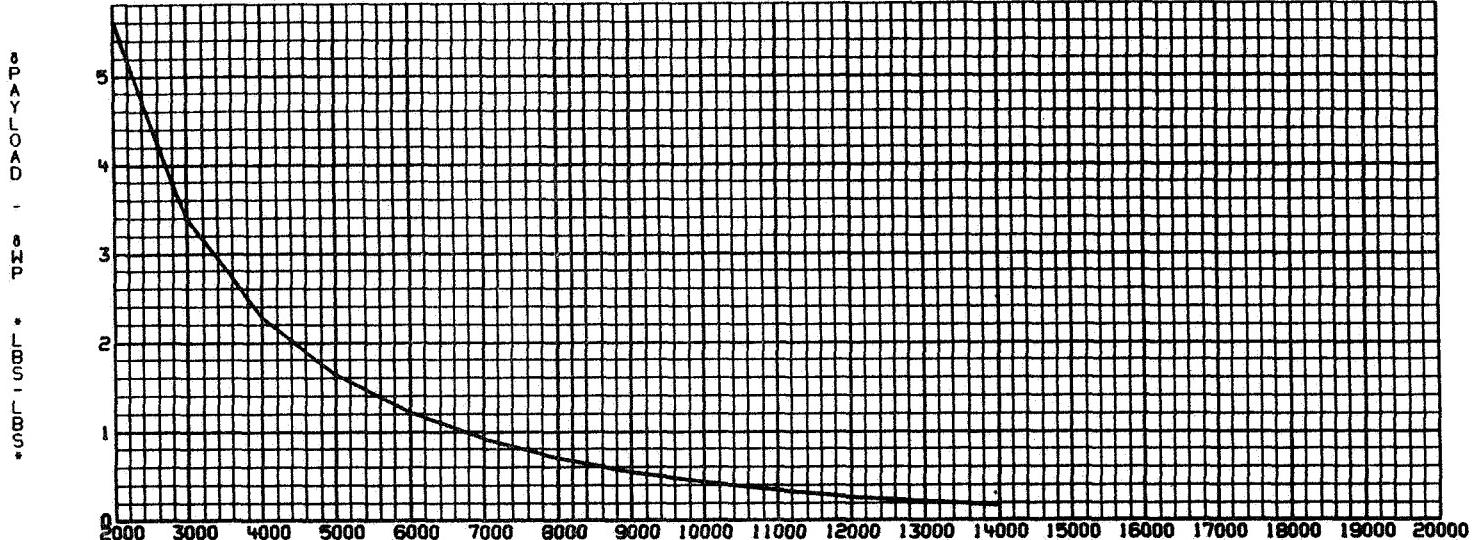
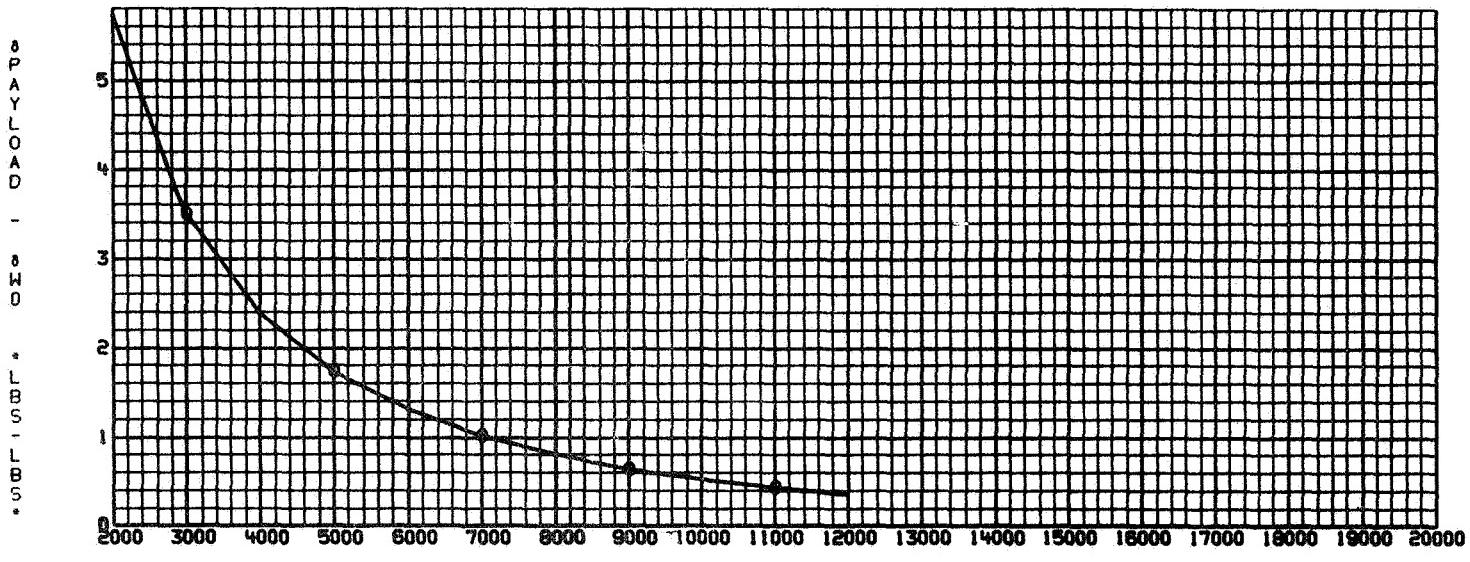


Figure 3-72

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-73

NOTE

**Offloaded propellant
in Mode 2 is not
a function of ΔV**

Figure 3-74

MODE 3

PAYLOAD DELIVERED
• = FIXED PROPELLANT 36295 LBS.
□ = FIXED IGNITION 15000 LBS.

36295 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE P/L ** REUSEABLE TUG
■ = FIXED IGNITION 65000 LBS.

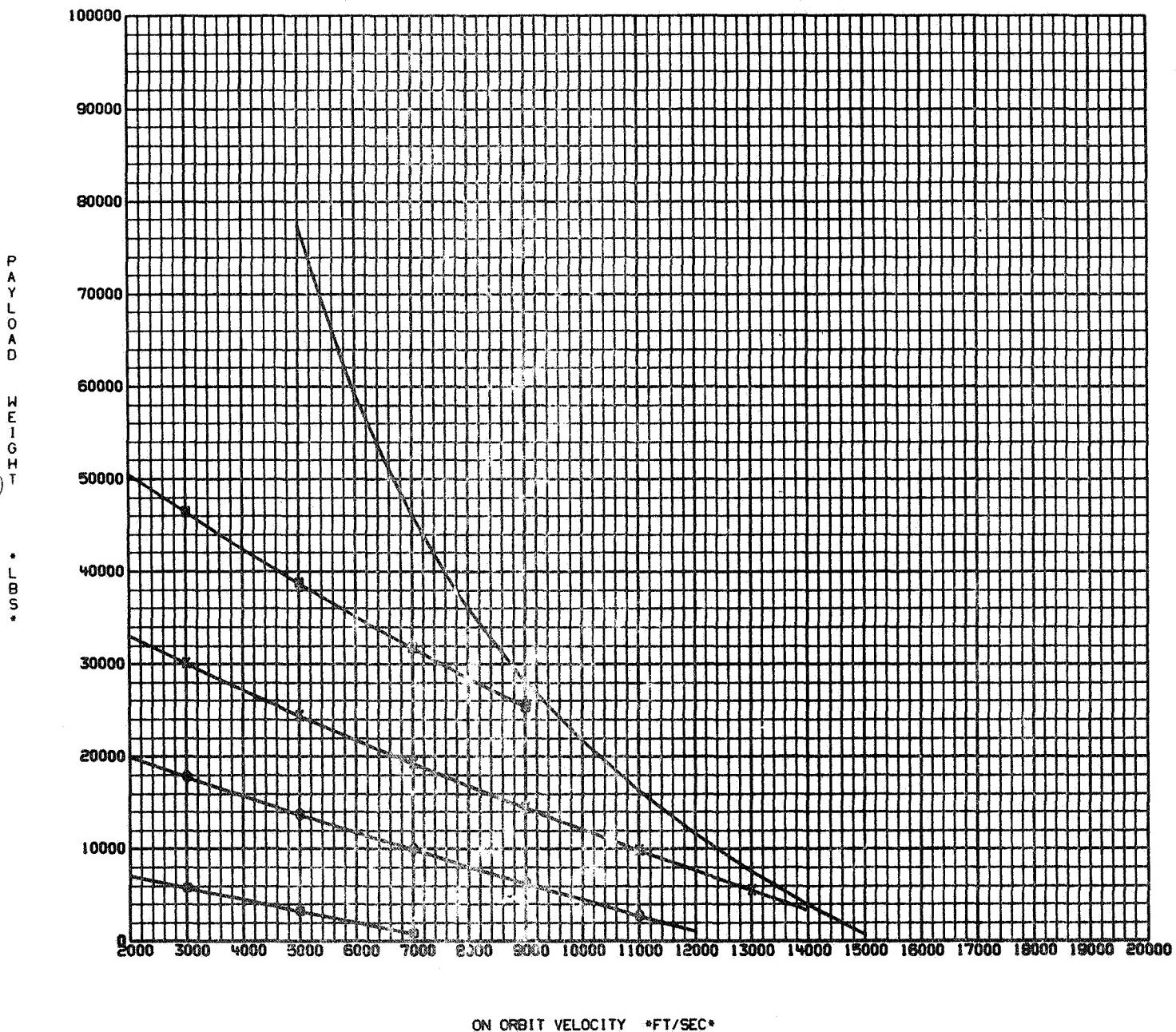
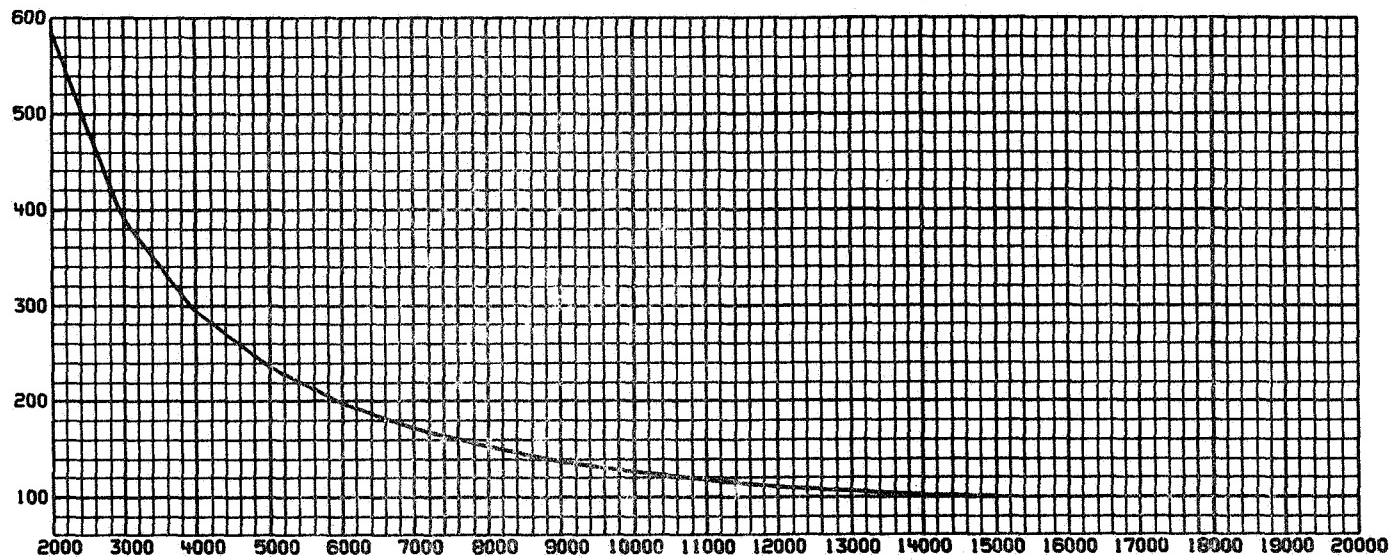


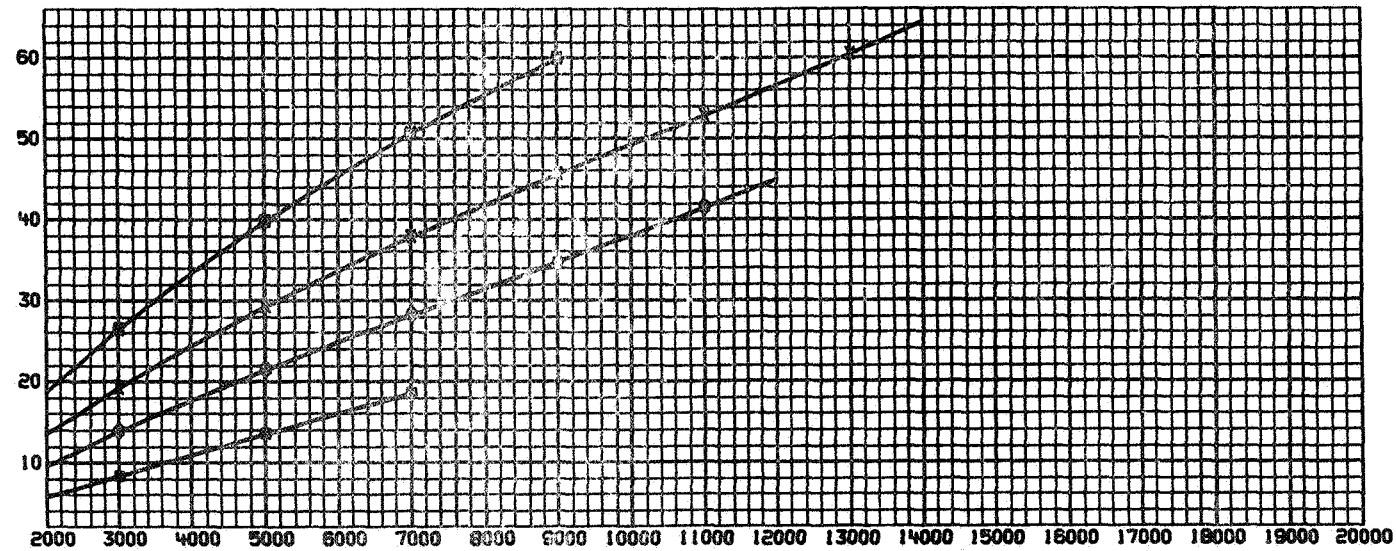
Figure 3-75

PAYLOAD DELIVERED
36295 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE P/L ** REUSEABLE TUG



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



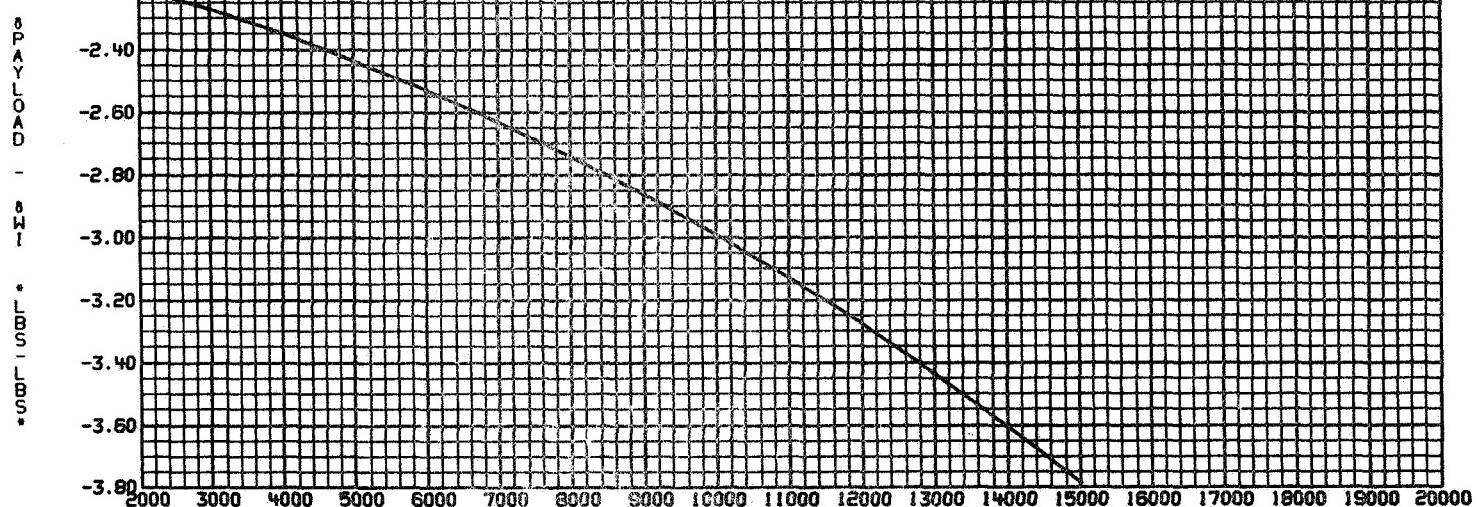
ON ORBIT VELOCITY *FT/SEC*

Figure 3-76

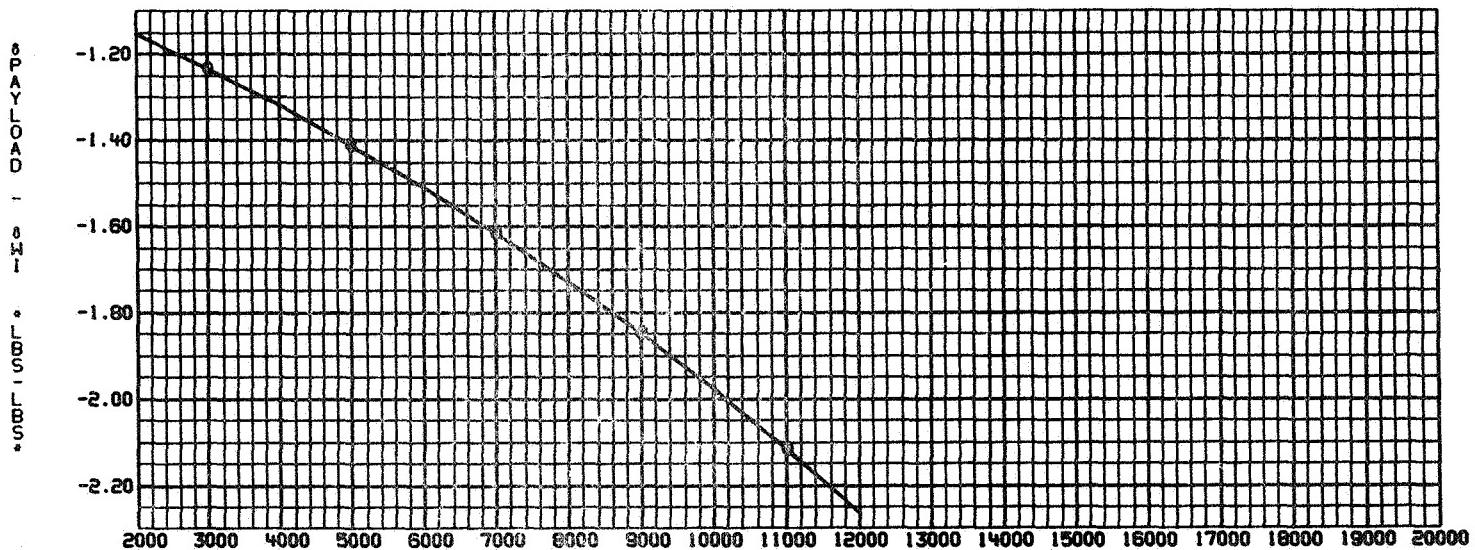
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-77

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT

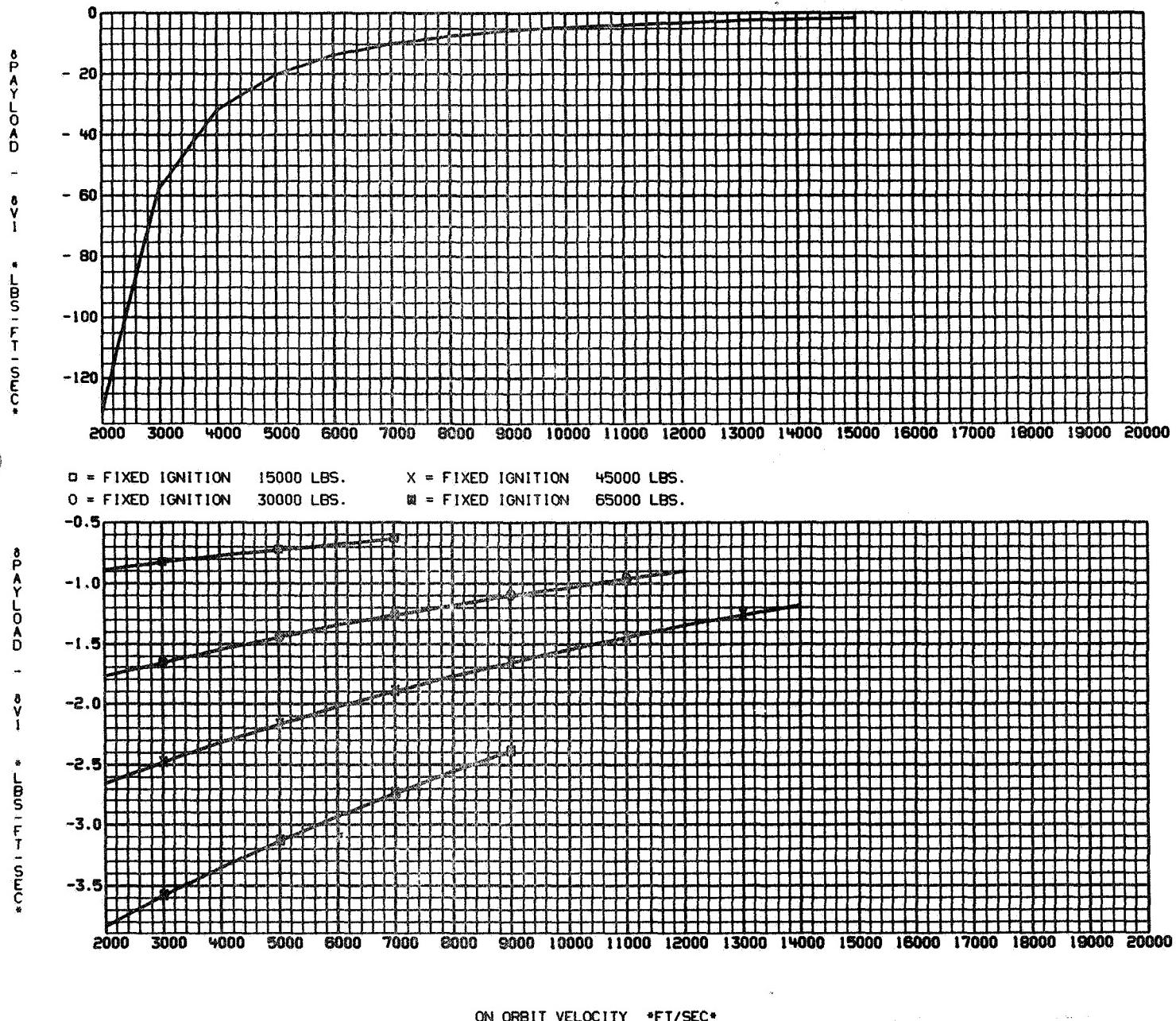


Figure 3-78

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT

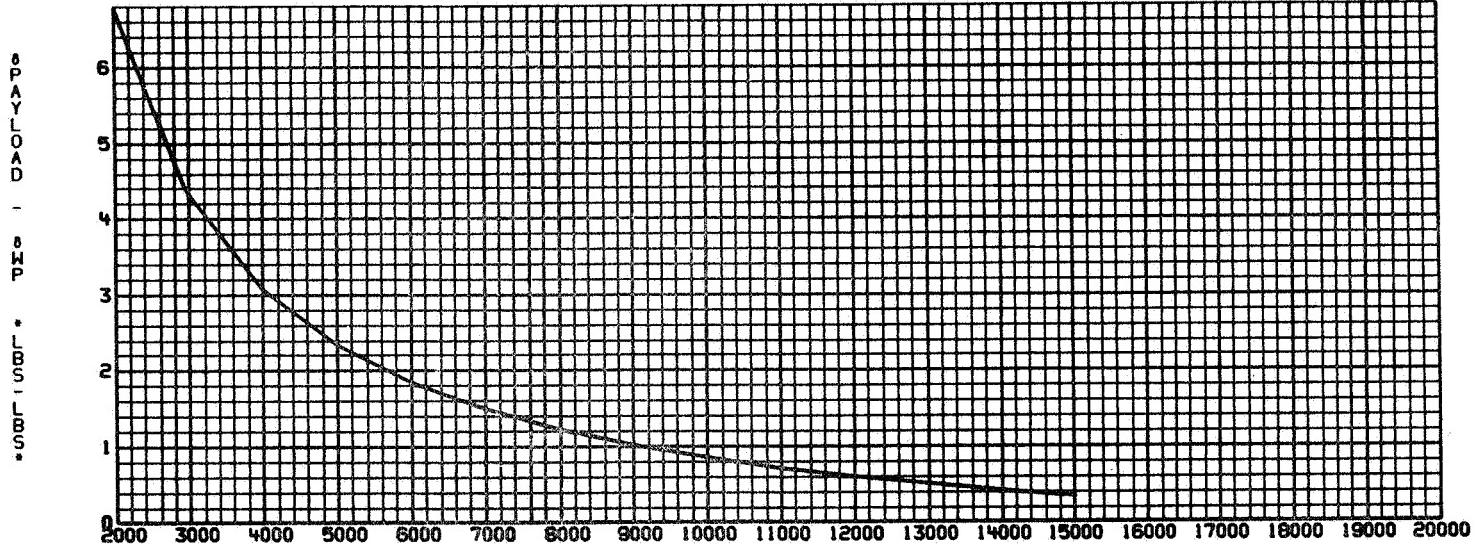
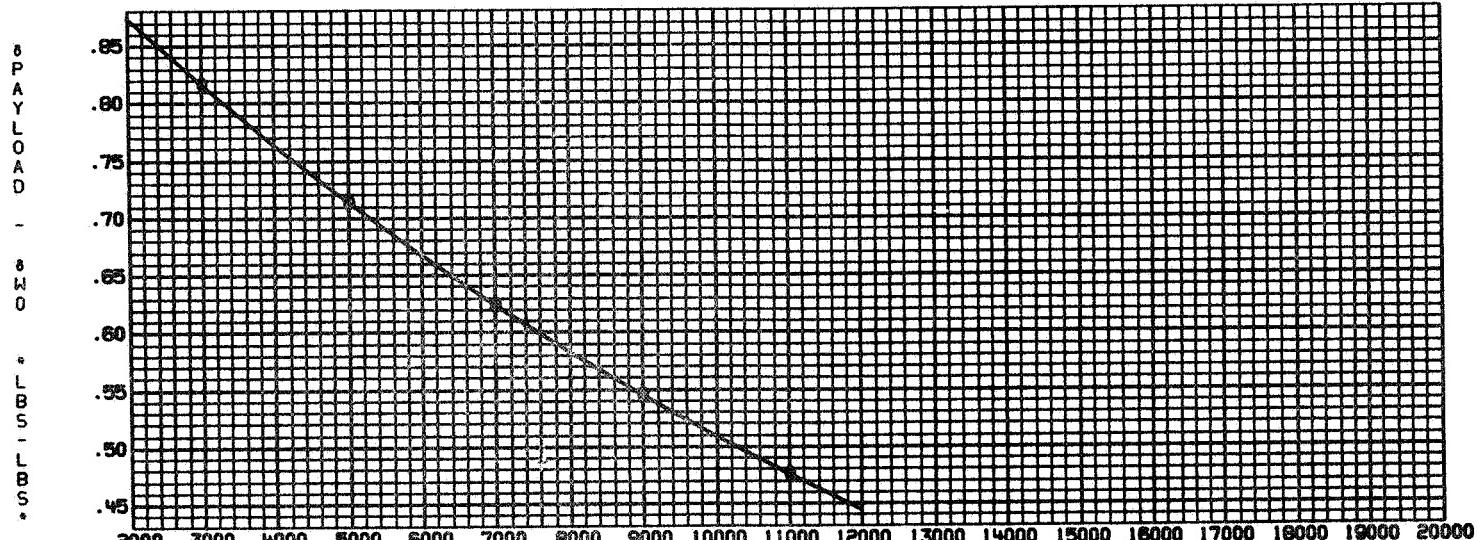


Figure 3-79

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-80

PAYOUT DELIVERED	FIXED IGNITION WEIGHTS	EXPENDABLE P/L ** REUSEABLE TUG
<input checked="" type="checkbox"/> = FIXED IGNITION 15000 LBS.	O = FIXED IGNITION 30000 LBS.	<input checked="" type="checkbox"/> = FIXED IGNITION 65000 LBS.
	X = FIXED IGNITION 45000 LBS.	

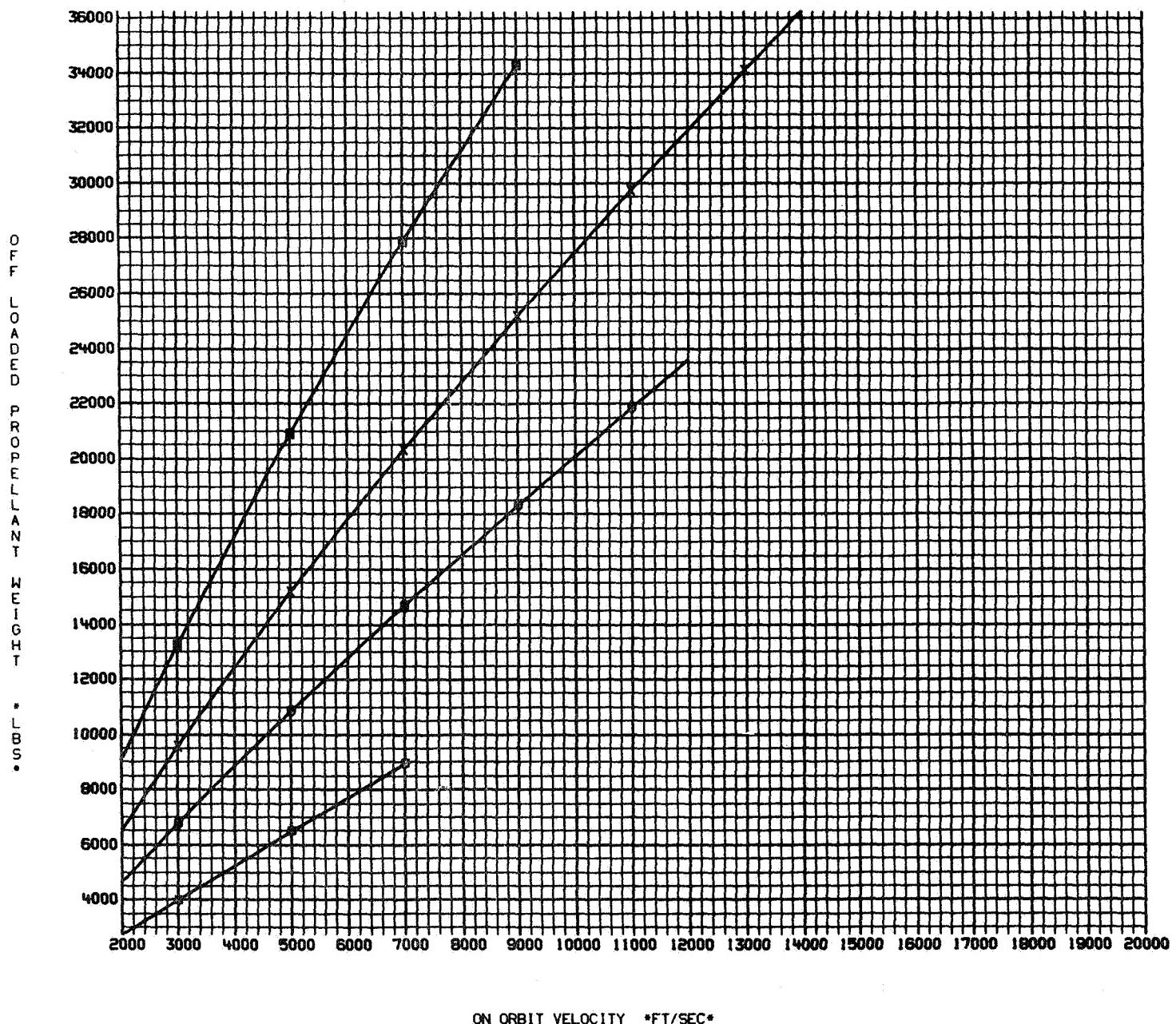


Figure 3-81

MODE 4

PAYOUT DELIVERED 36295 LBS. FIXED PROPELLANT WEIGHT 36295 LBS.
 = FIXED PROPELLANT 36295 LBS. O = FIXED IGNITION 30000 LBS.
 = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.

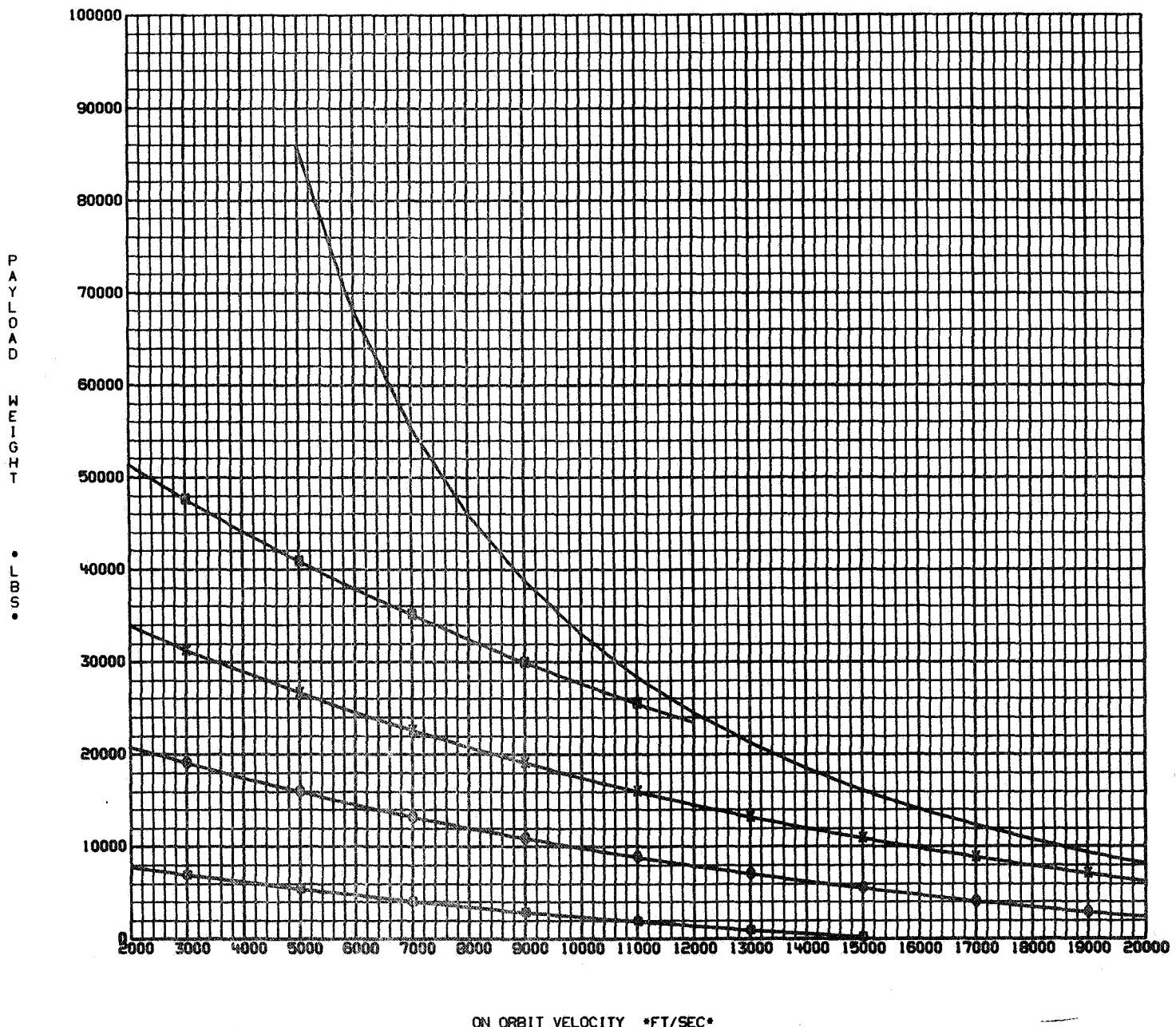
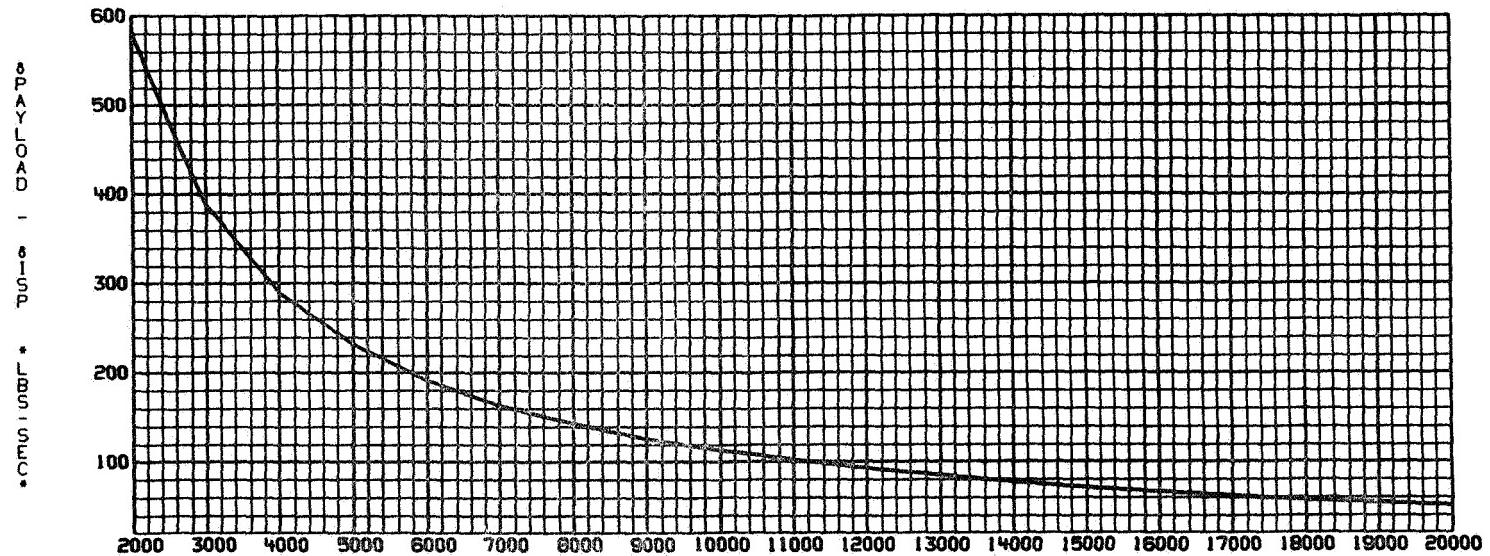


Figure 3-82

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT



D = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.

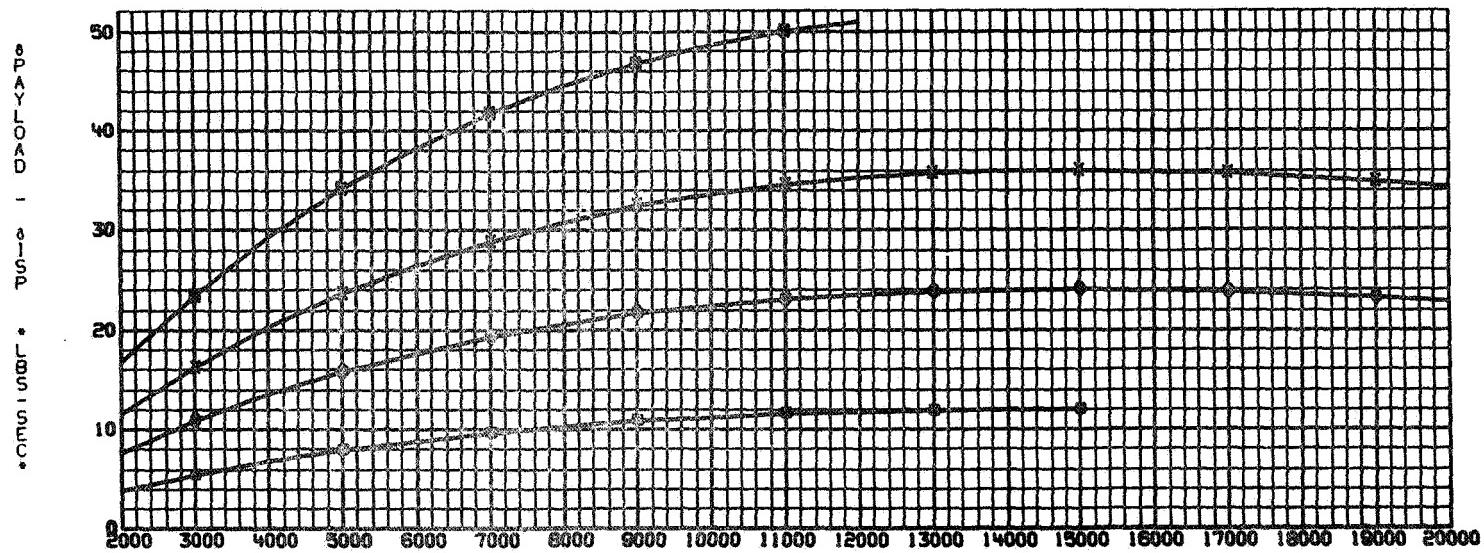
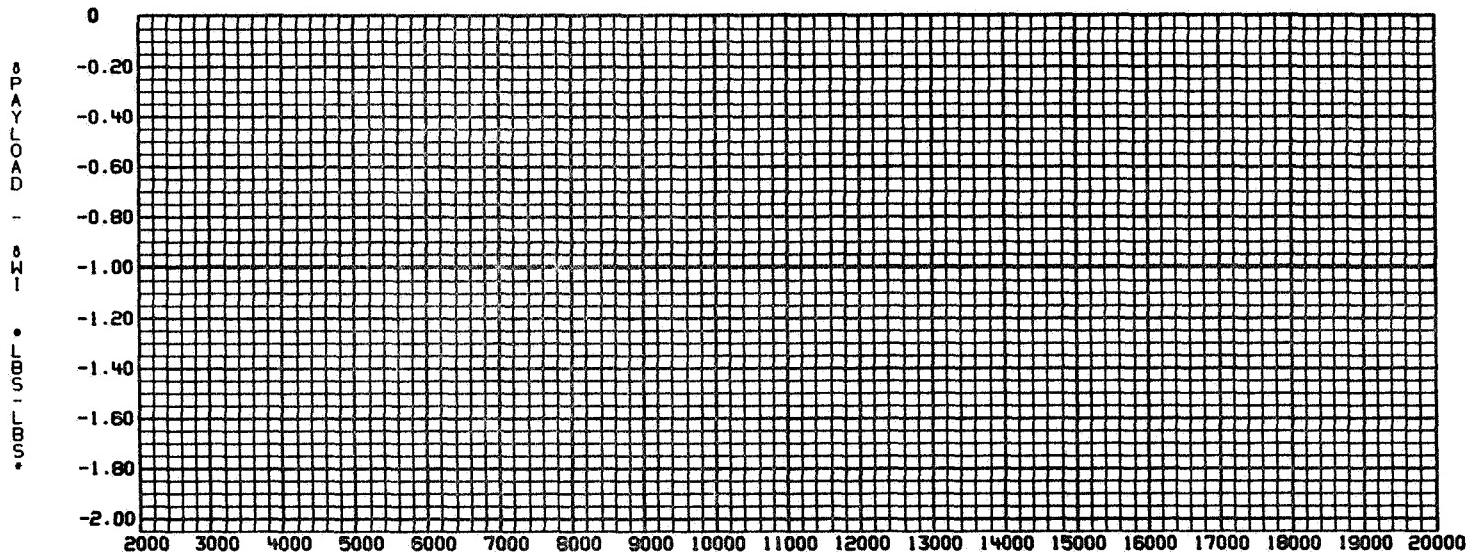


Figure 3-83

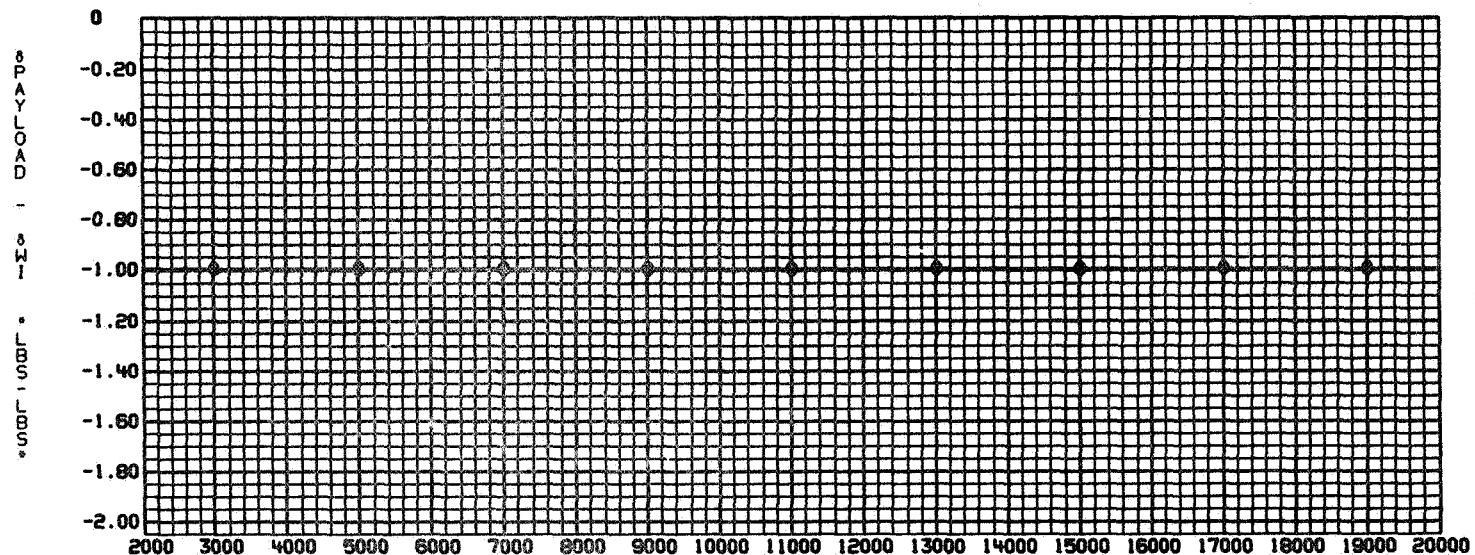
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-84

PAYOUT DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT

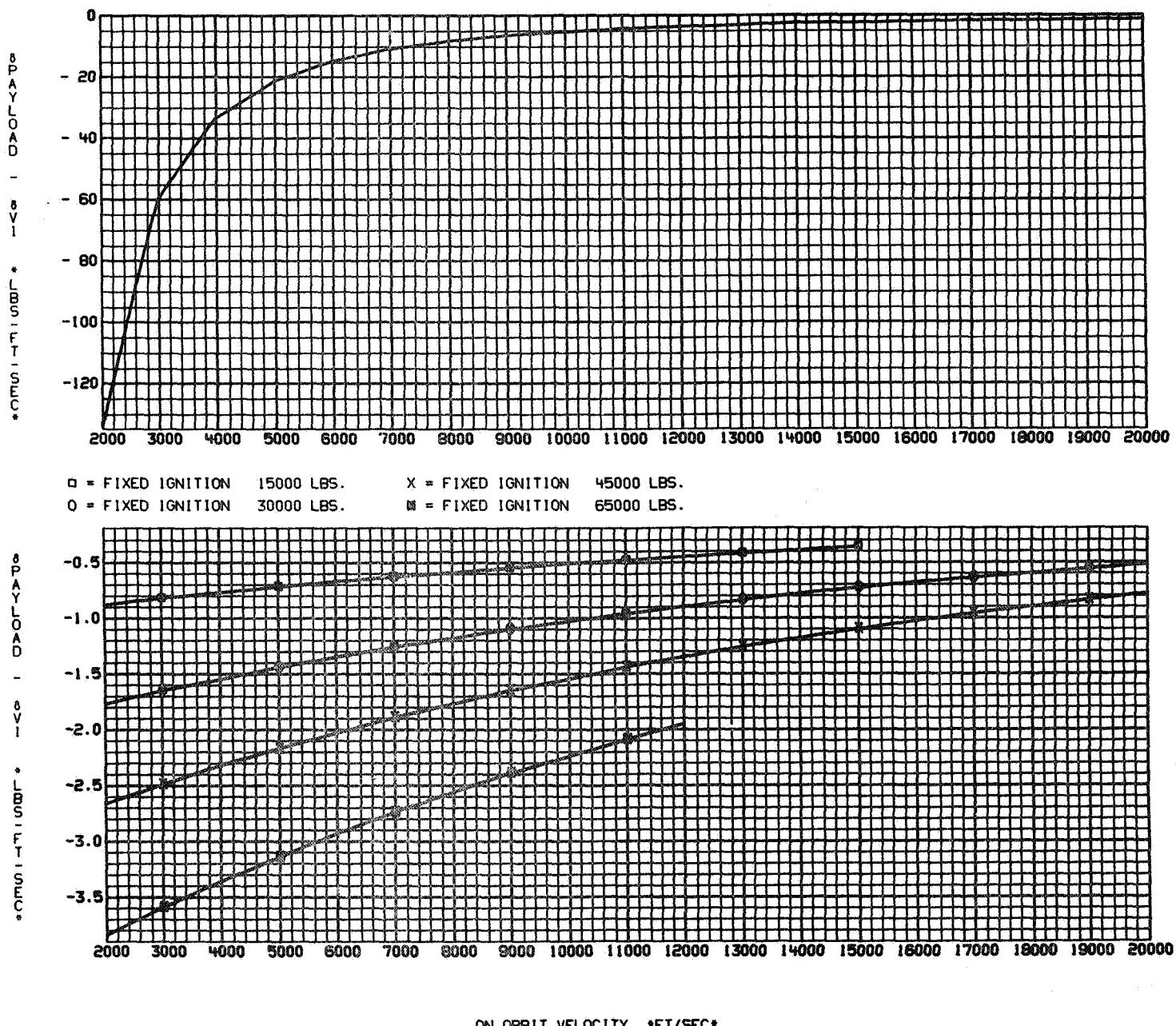


Figure 3-85

PAYLOAD DELIVERED
36295 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

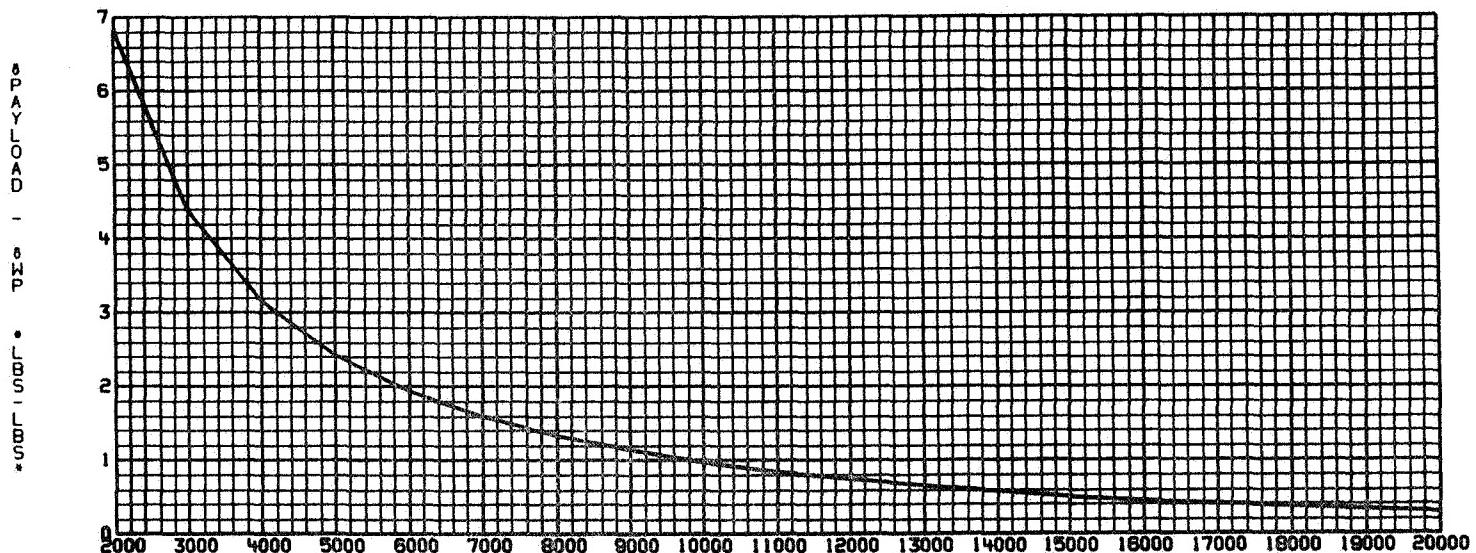
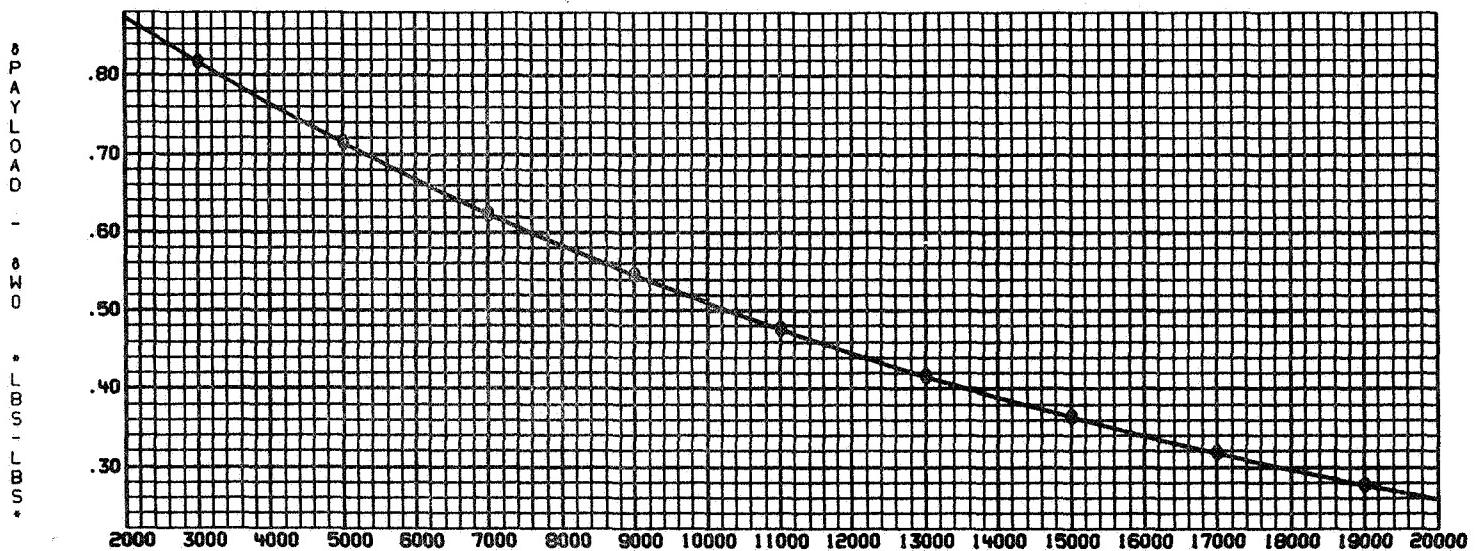


Figure 3-86

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-87

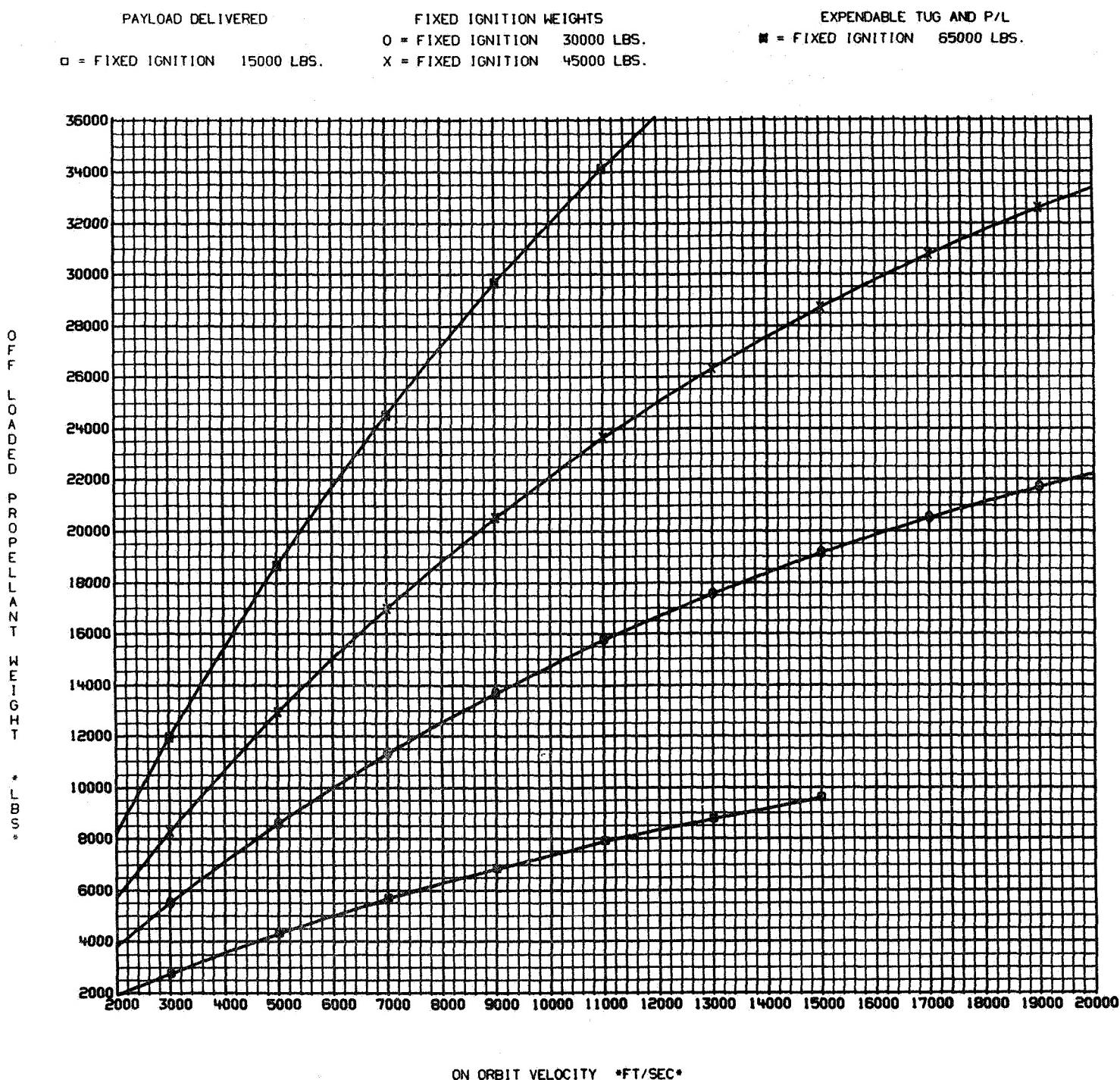


Figure 3-88

MODE 1

PAYLOAD DELIVERED
• = FIXED PROPELLANT 47830 LBS.
□ = FIXED IGNITION 15000 LBS.

47B30 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

ROUND TRIPPED P/L CAPABILITY
■ = FIXED IGNITION 65000 LBS.

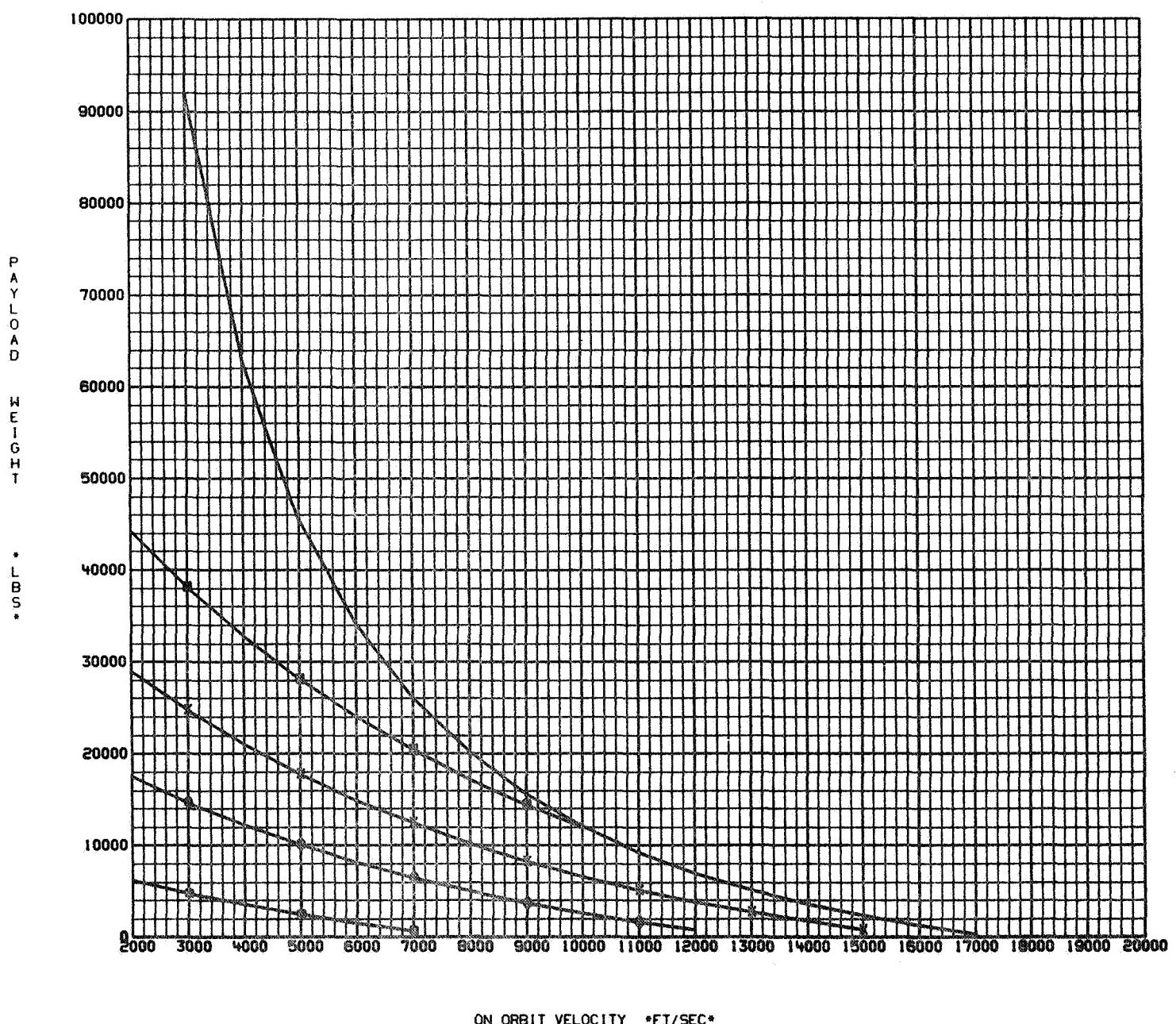
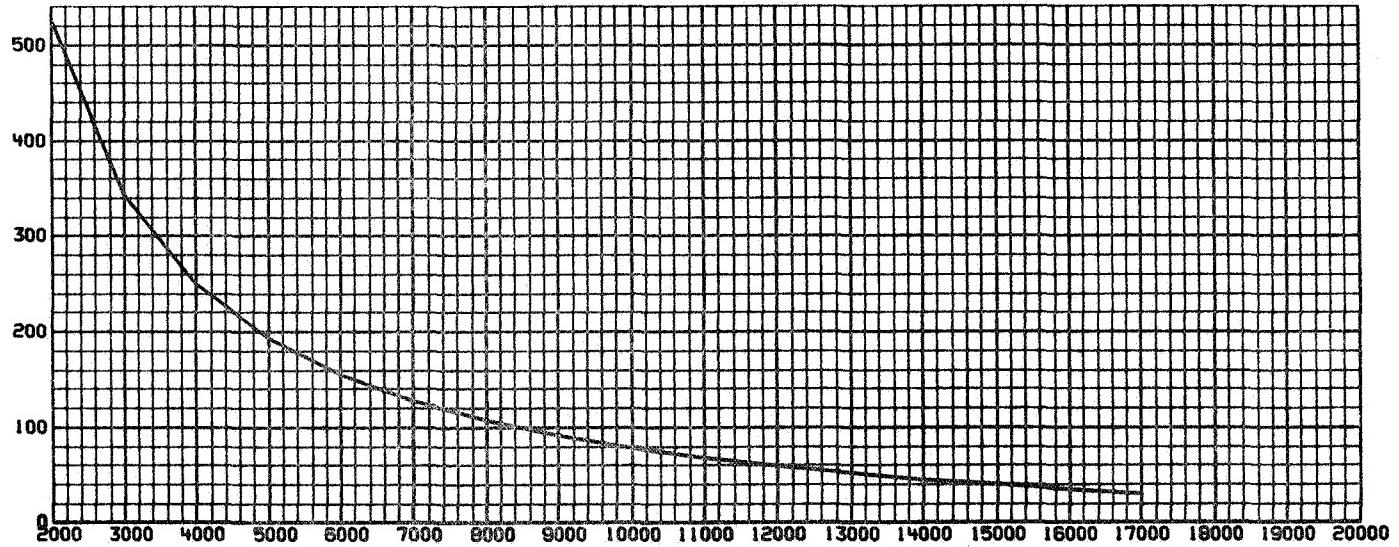


Figure 3-89

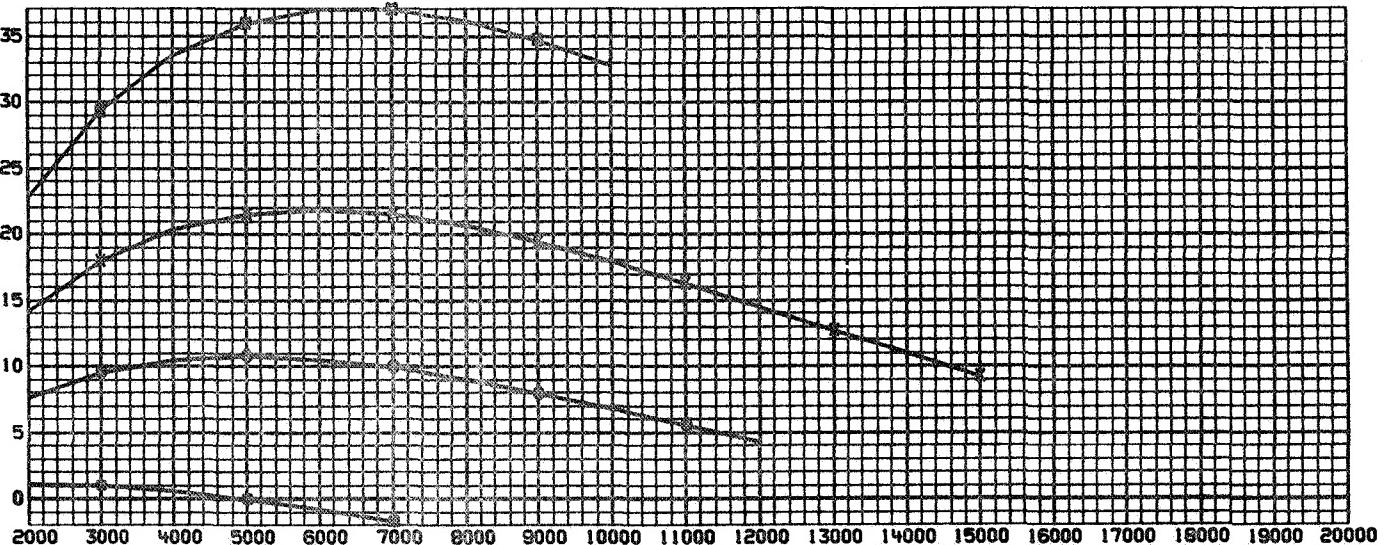
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



■ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



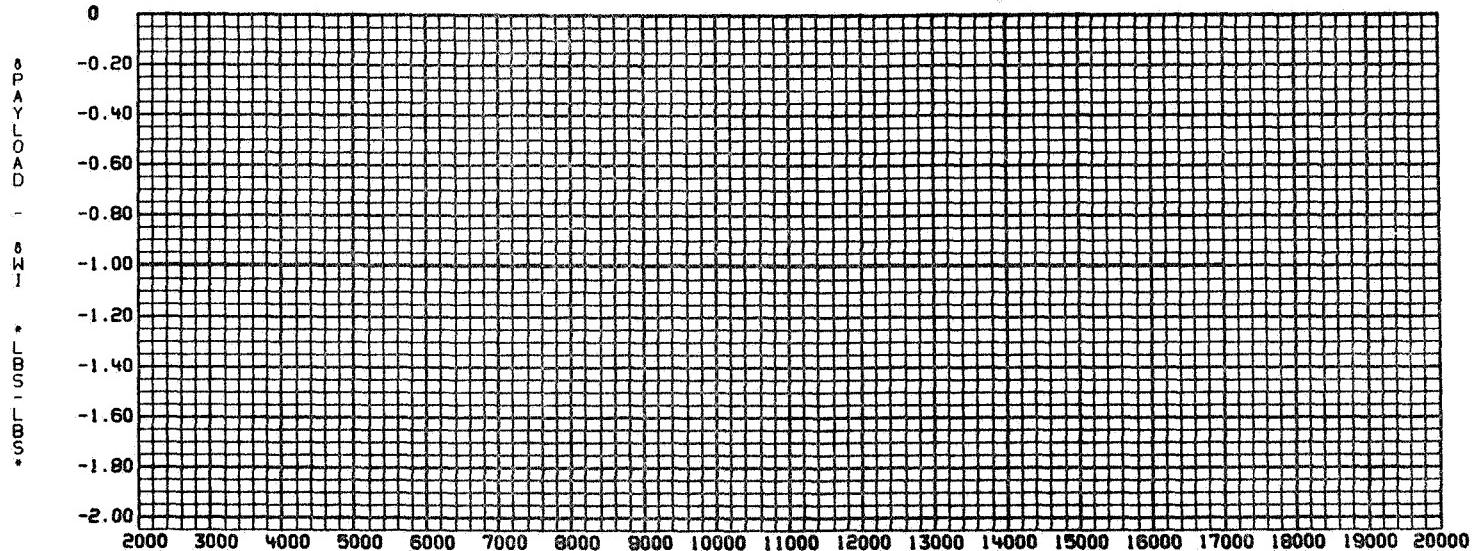
ON ORBIT VELOCITY *FT/SEC*

Figure 3-90

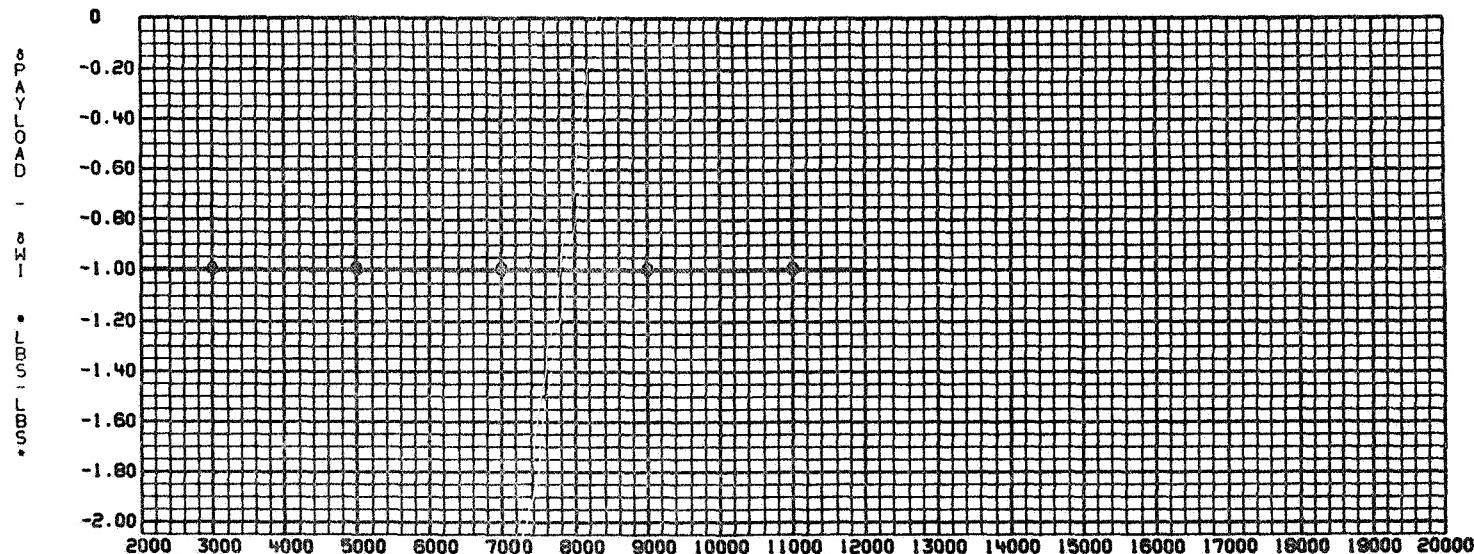
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



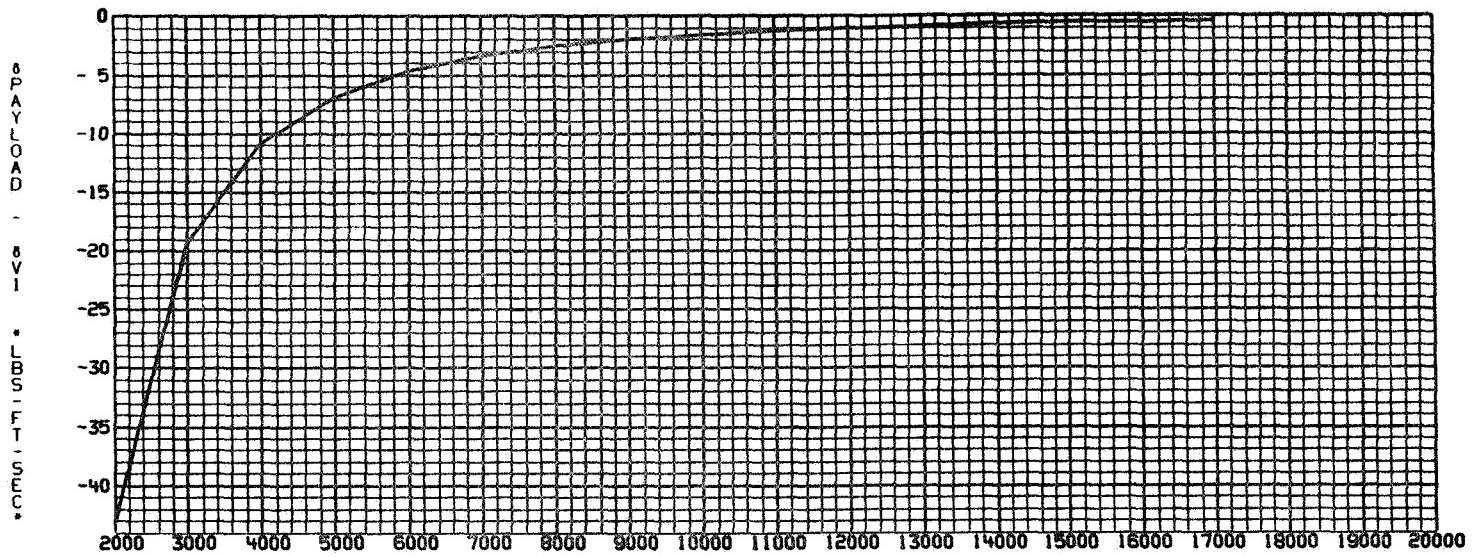
ON ORBIT VELOCITY *FT/SEC*

Figure 3-91

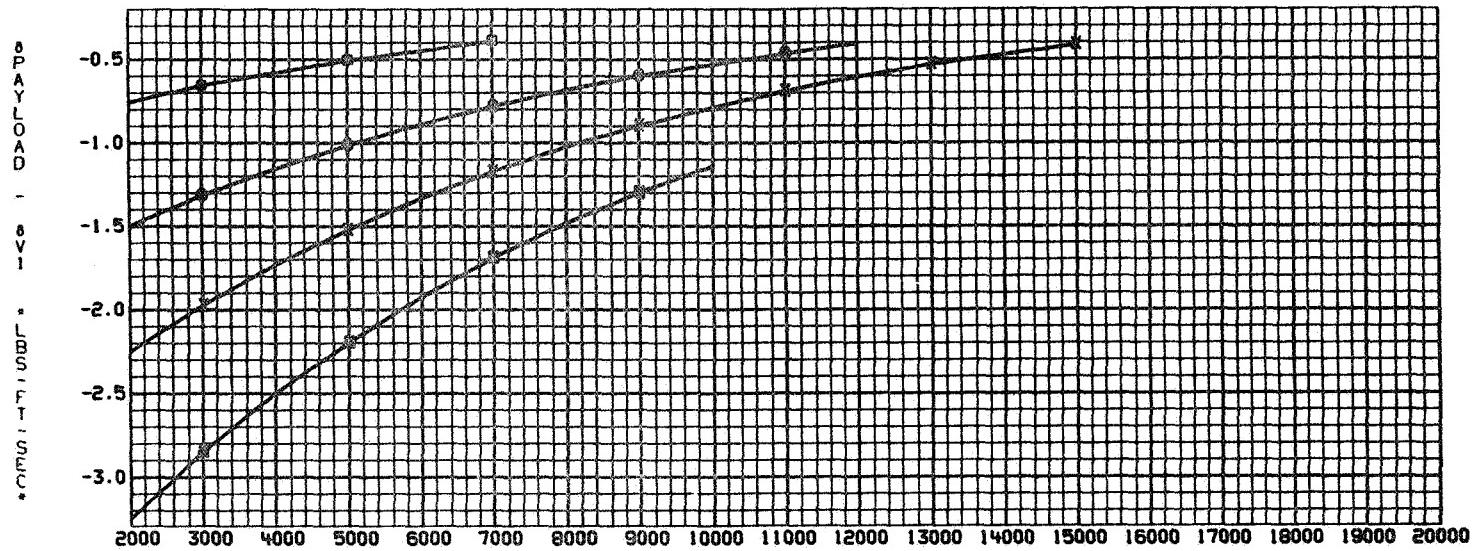
PAYOUT DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ▨ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-92

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

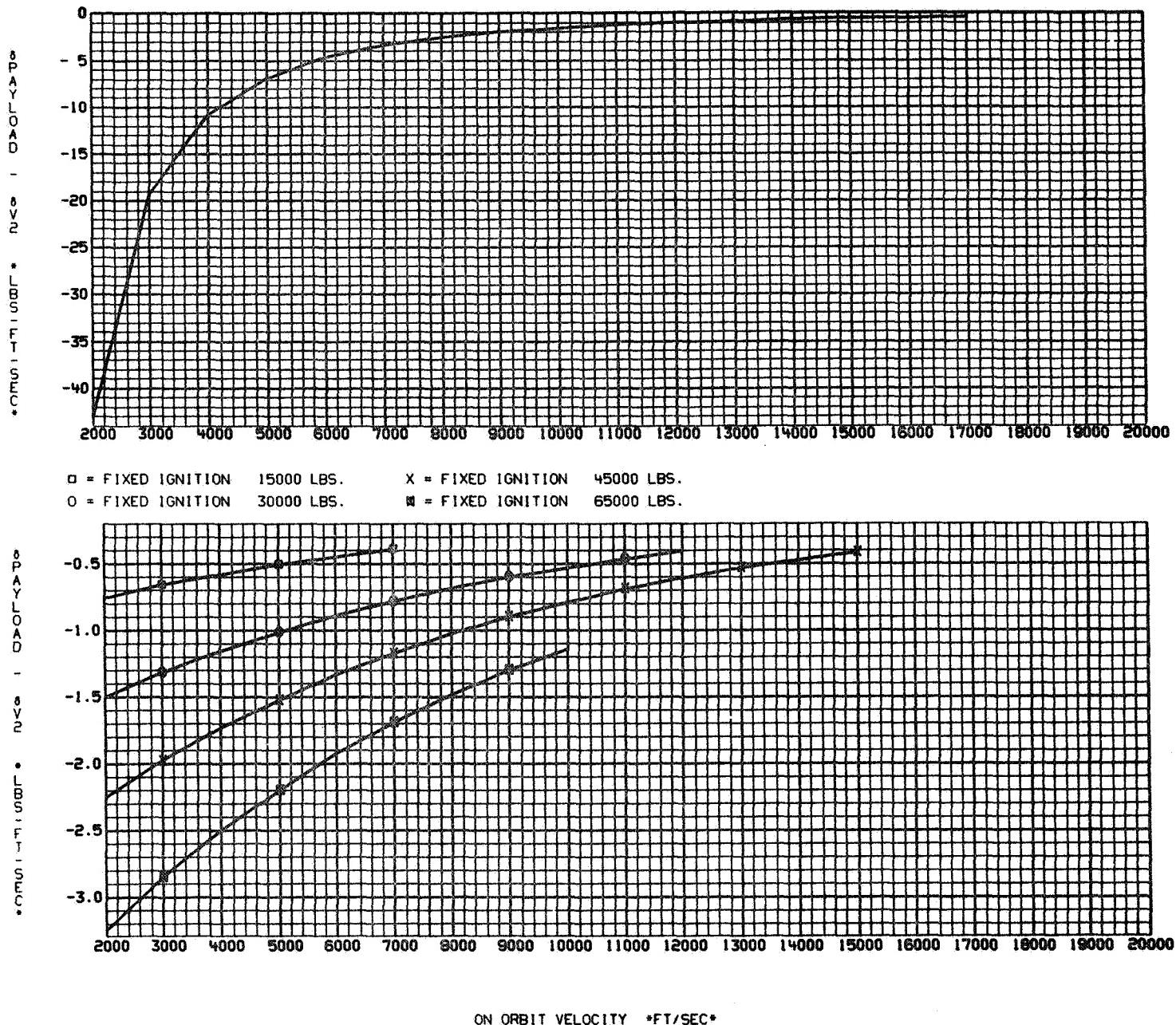


Figure 3-93

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

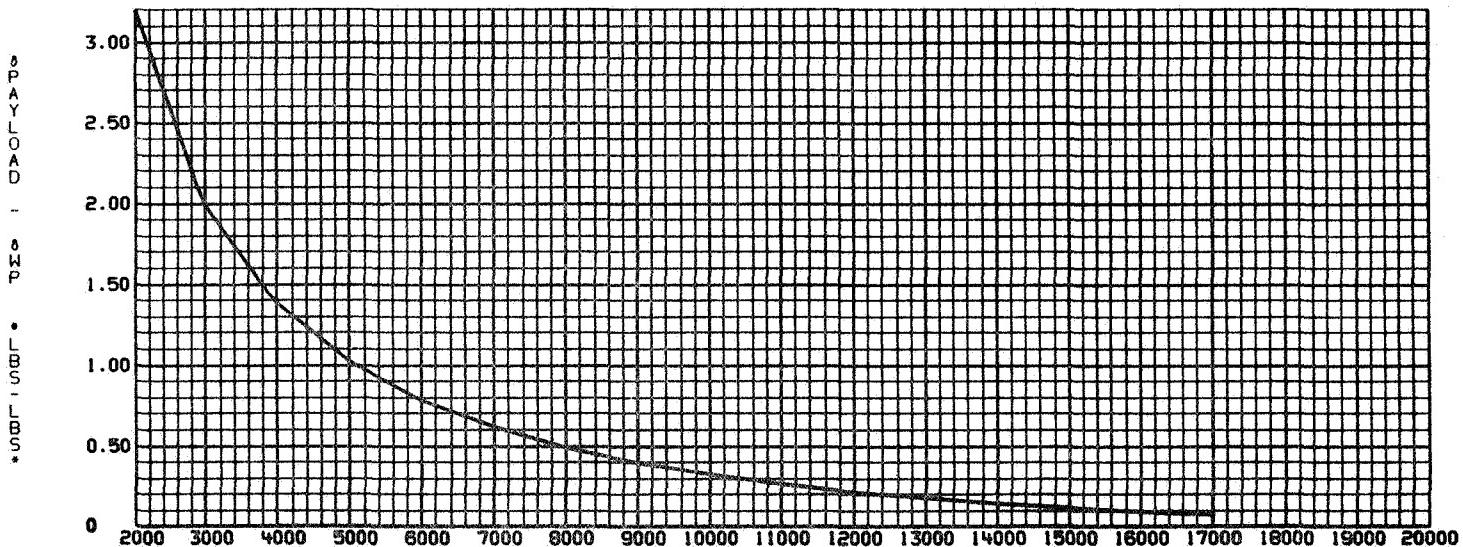


Figure 3-94

ALL FIXED IGNITION WEIGHTS

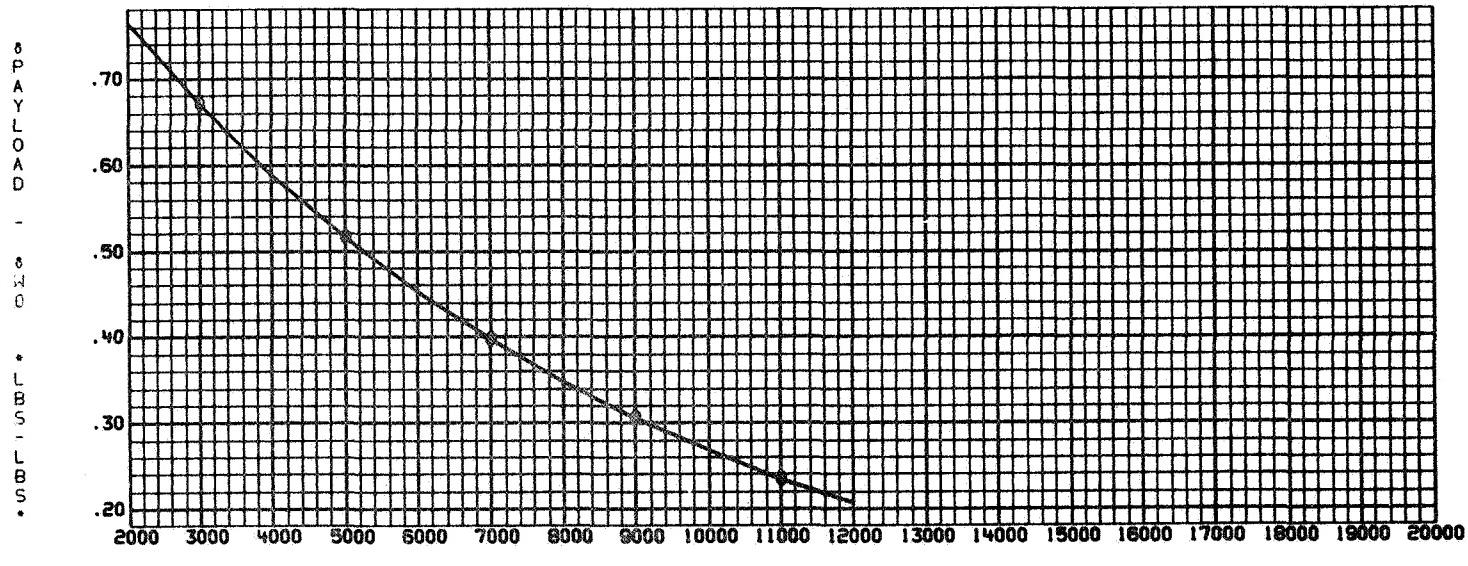
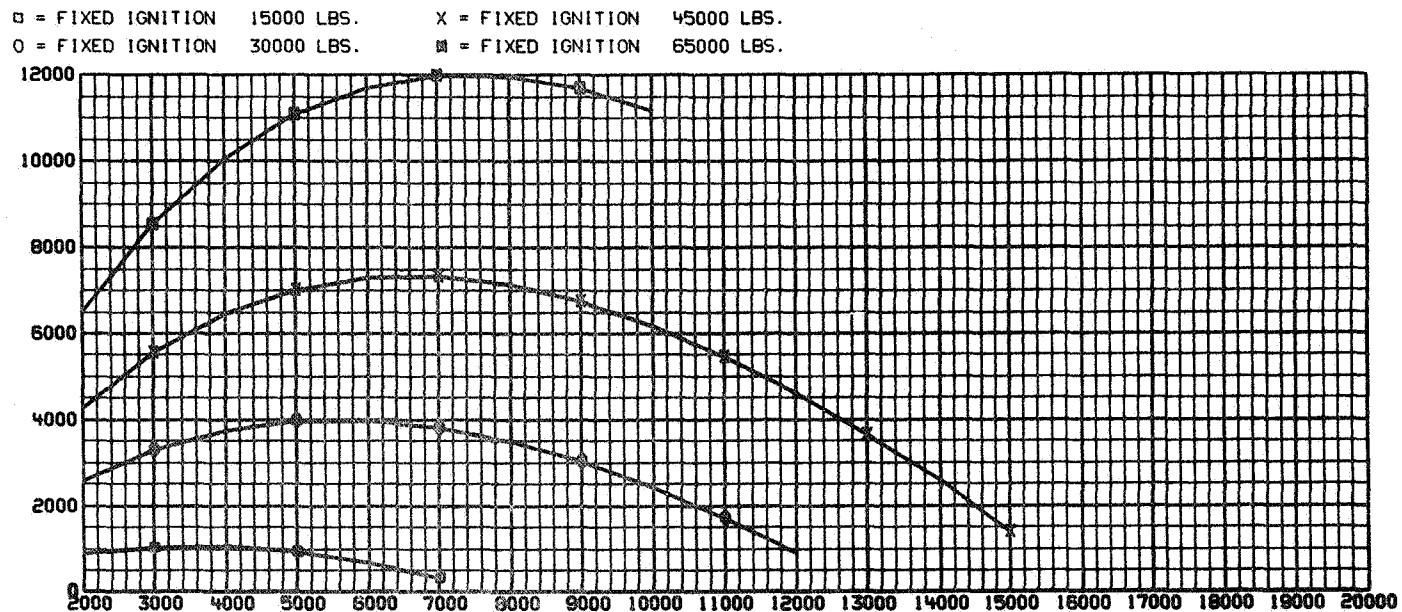
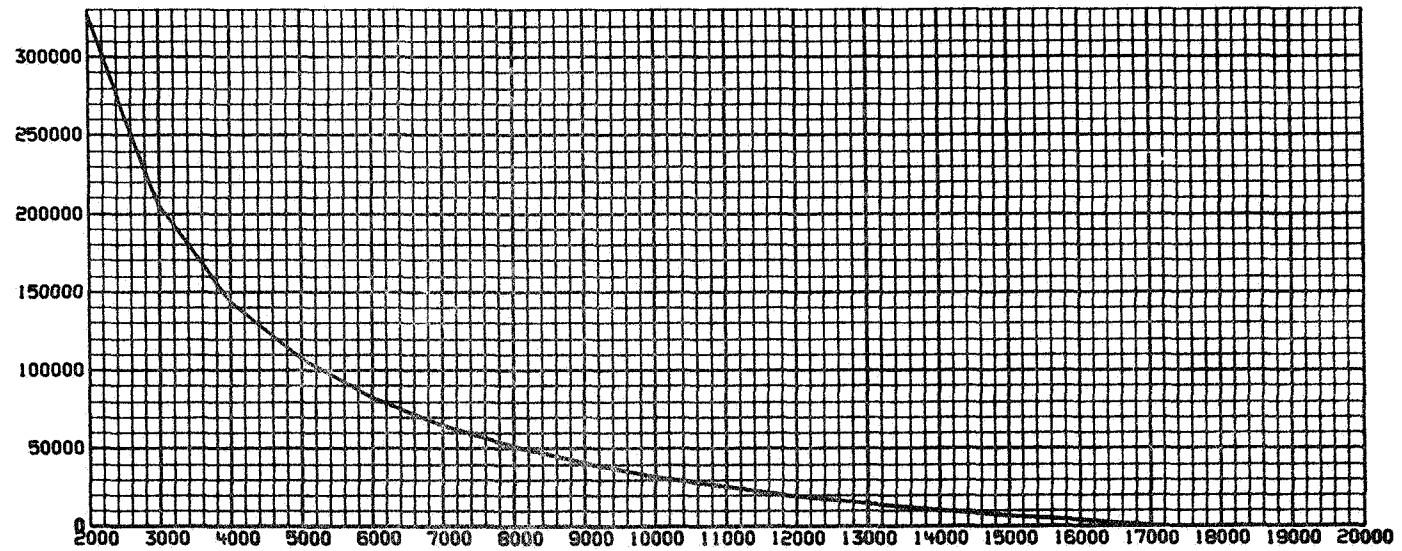


Figure 3-95

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-96

PAYLOAD DELIVERED

FIXED IGNITION WEIGHTS
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

ROUND TRIPPED P/L CAPABILITY
■ = FIXED IGNITION 65000 LBS.

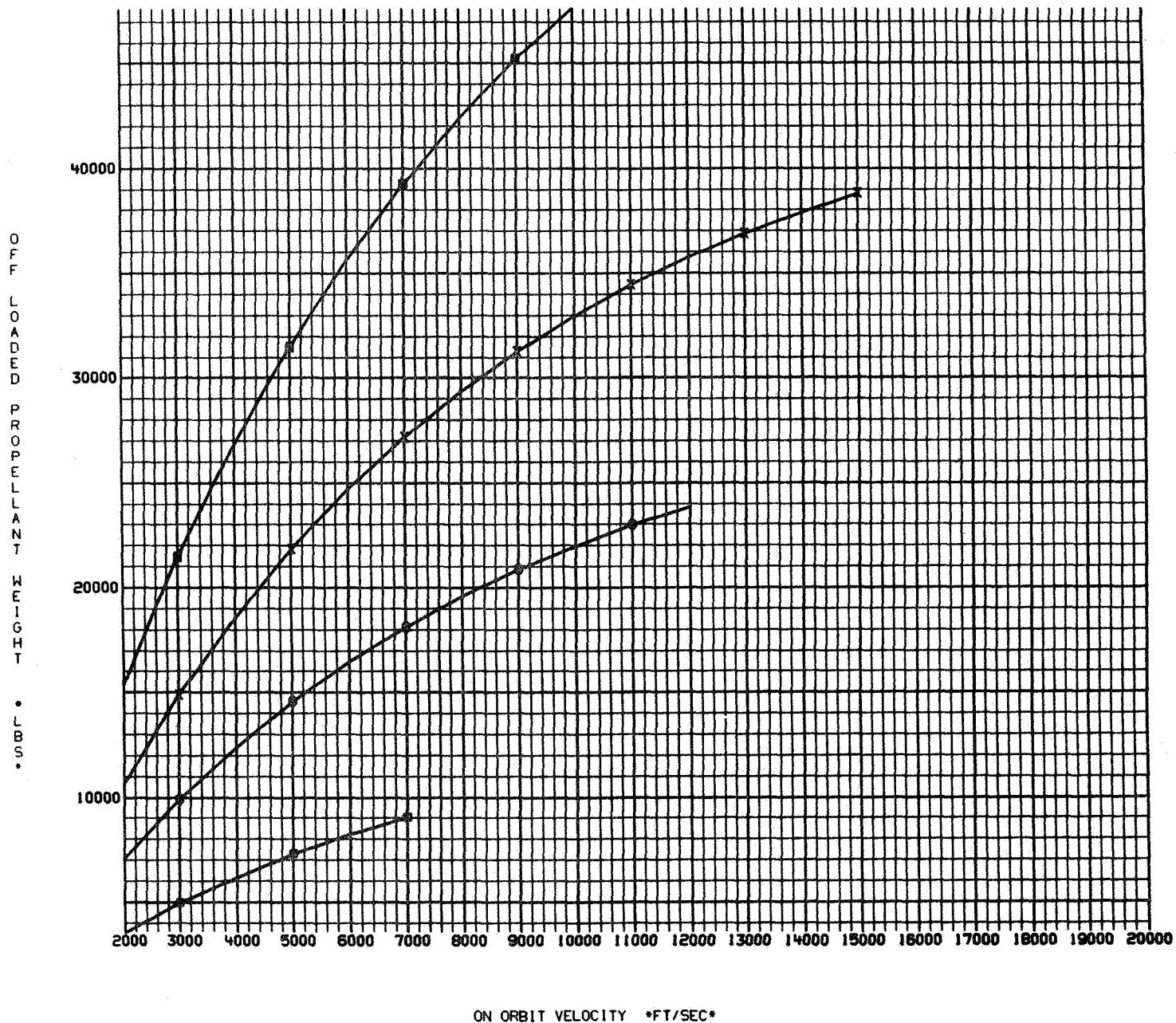


Figure 3-97

MODE 2

PAYOUT RETURNED 47830 LBS. FIXED PROPELLANT WEIGHT TUG - P/L RETRIEVAL CAPABILITY
- = FIXED PROPELLANT 47830 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

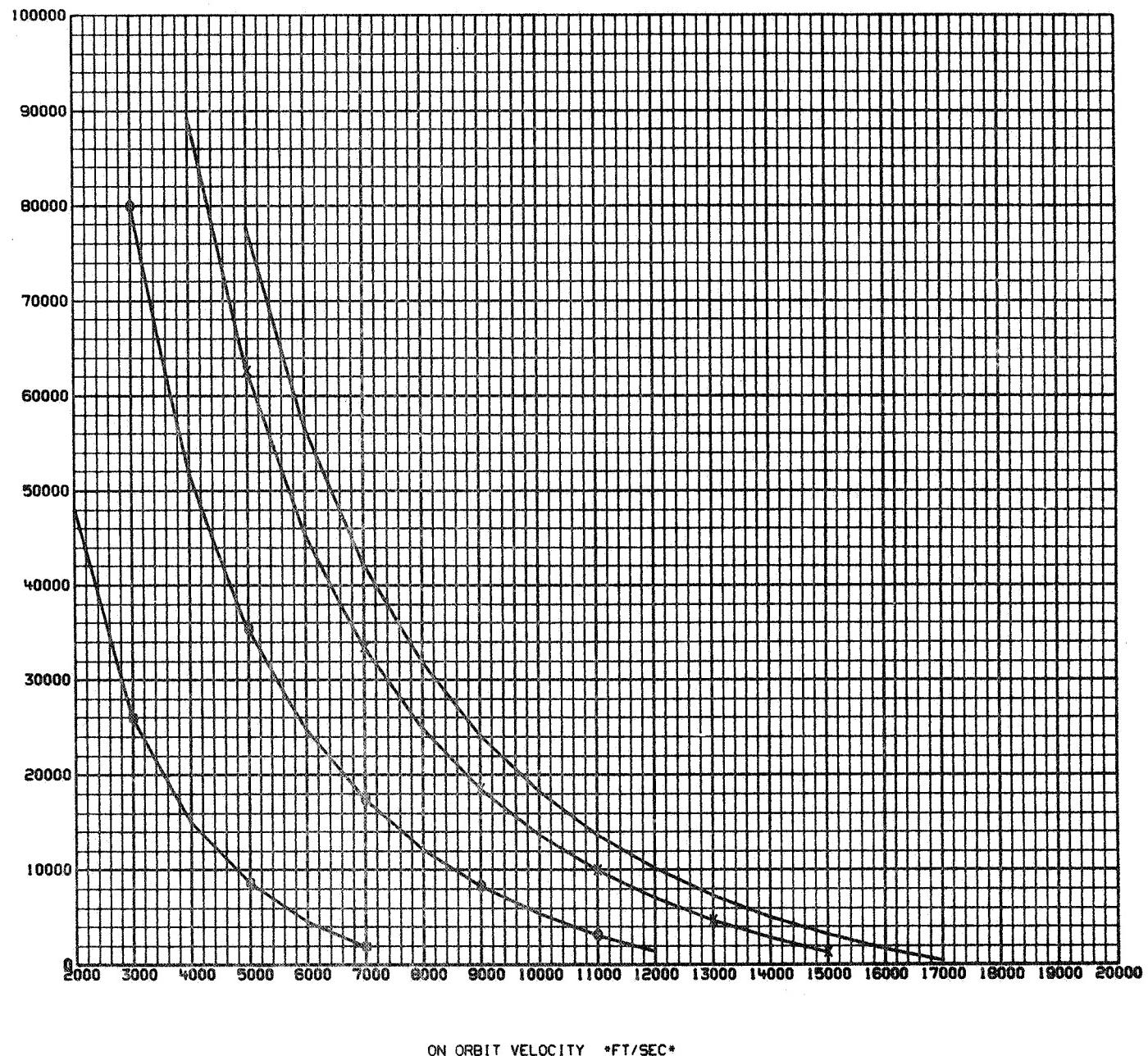
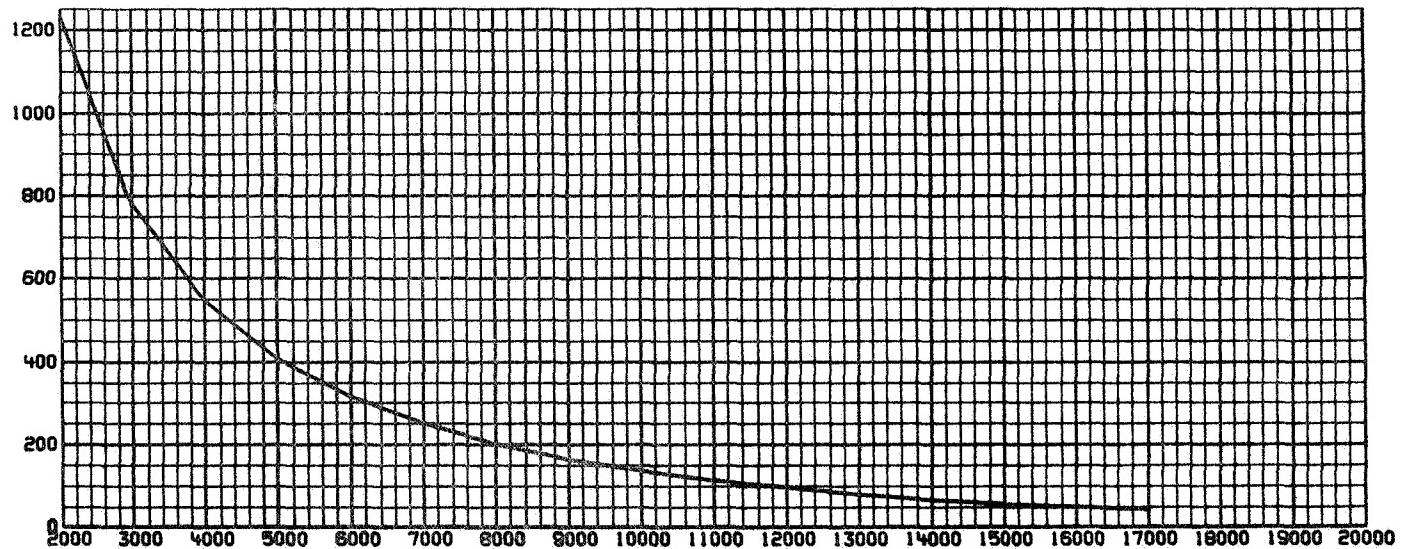


Figure 3-98

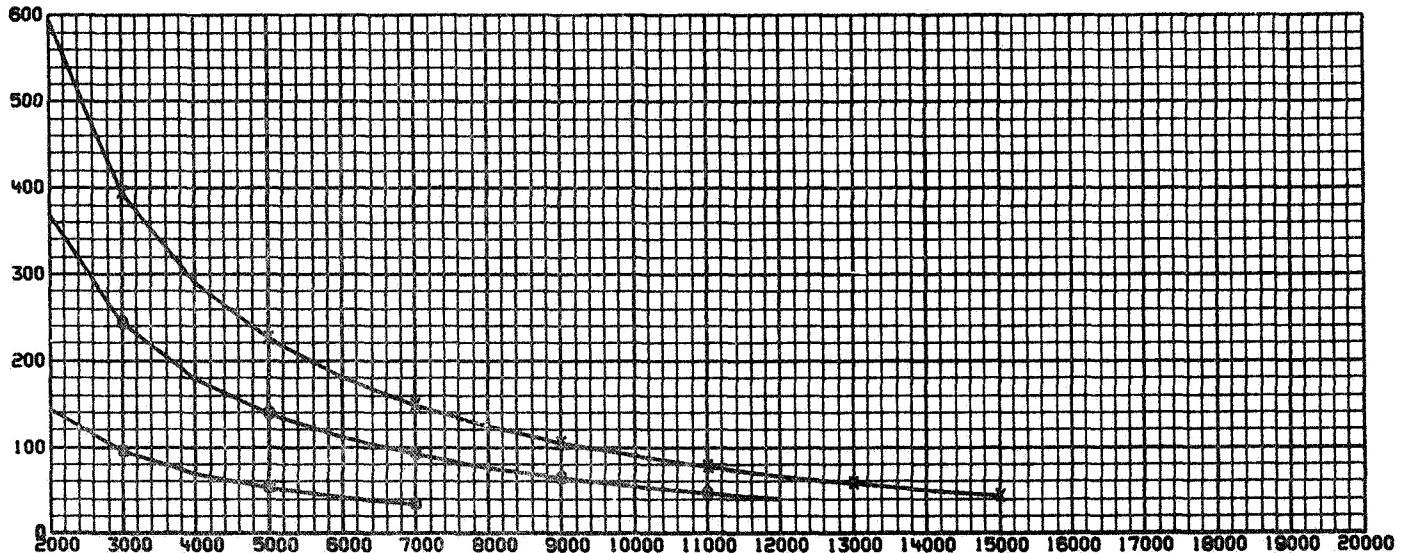
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. × = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



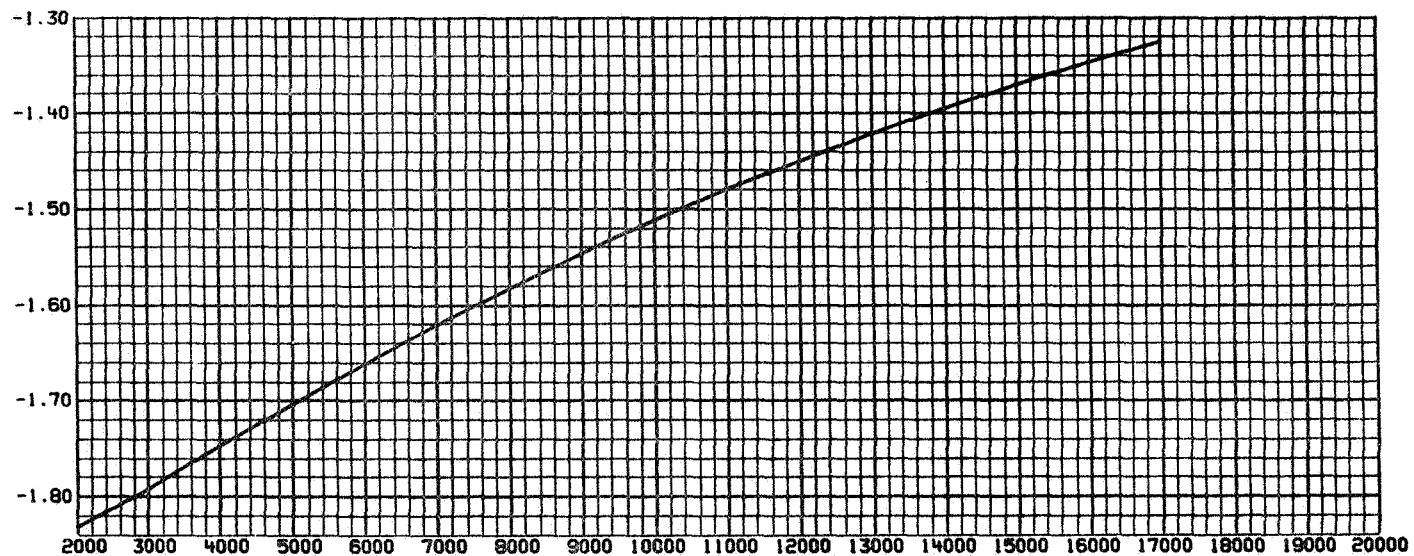
ON ORBIT VELOCITY *FT/SEC*

Figure 3-99

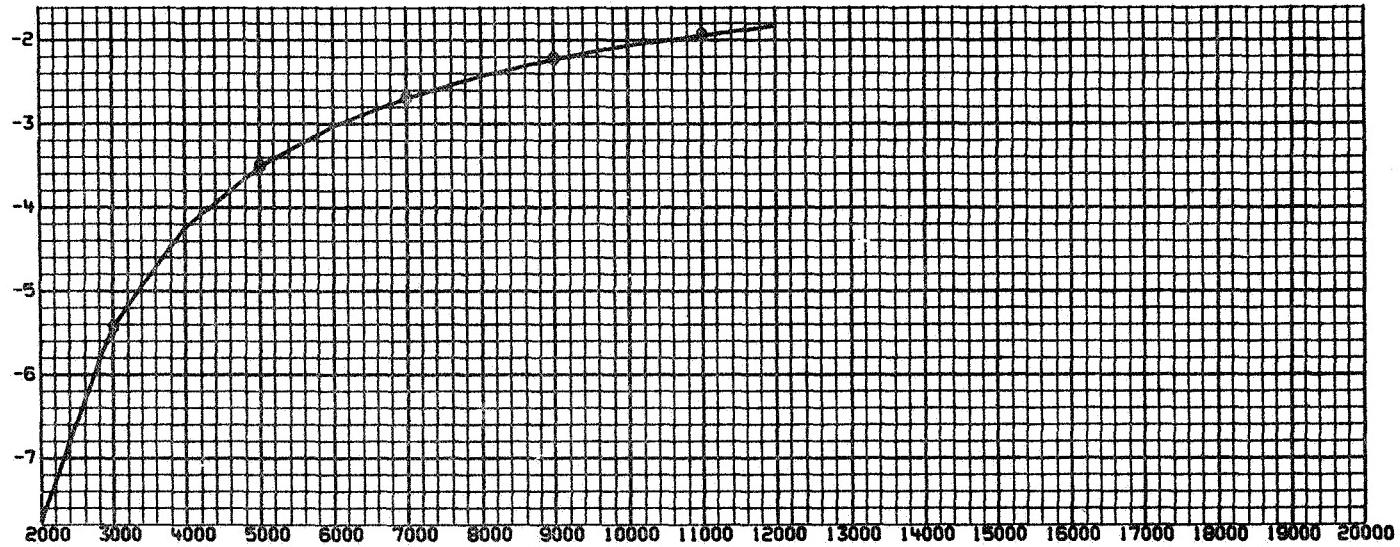
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



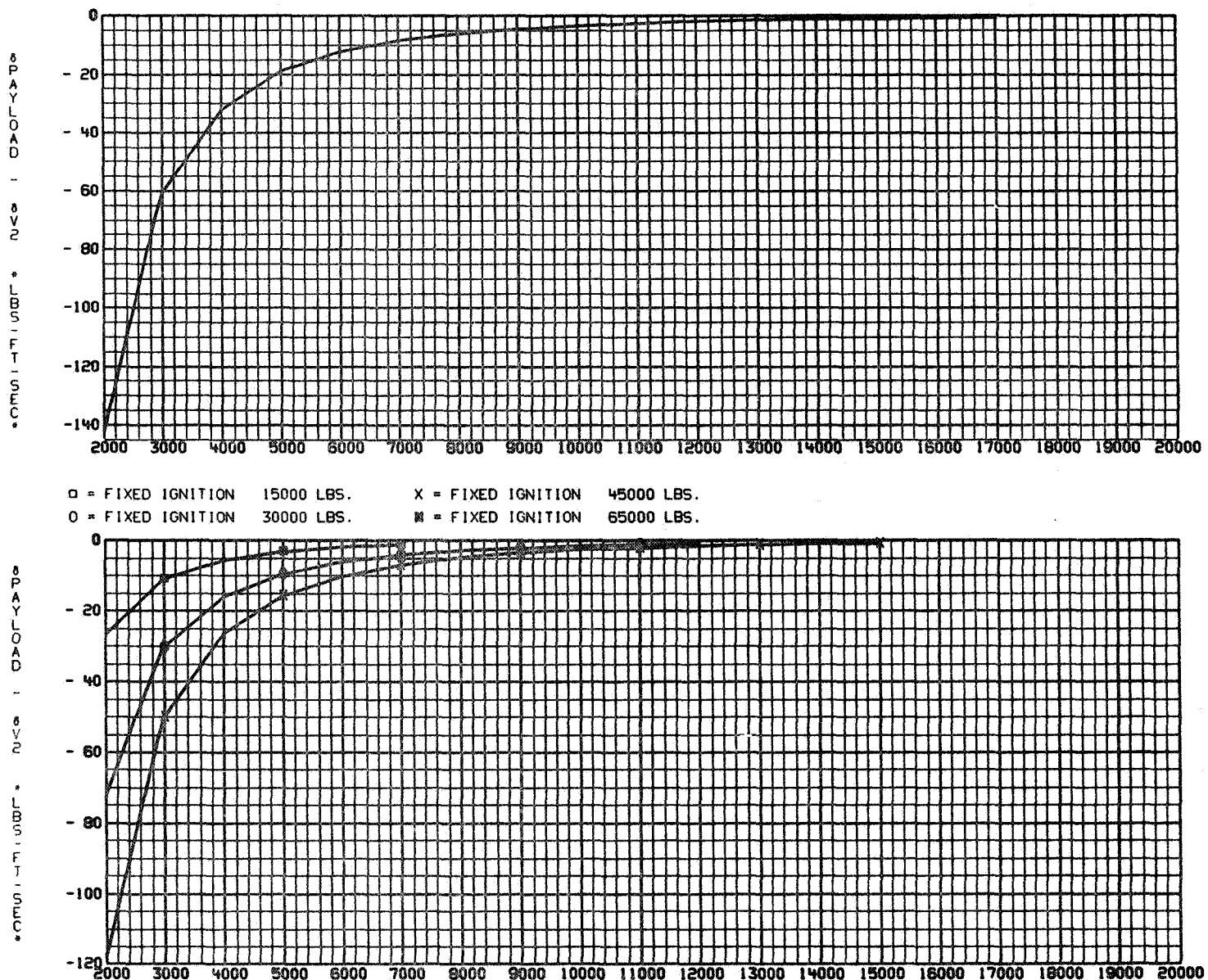
ON ORBIT VELOCITY *FT/SEC*

Figure 3-100

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-101

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

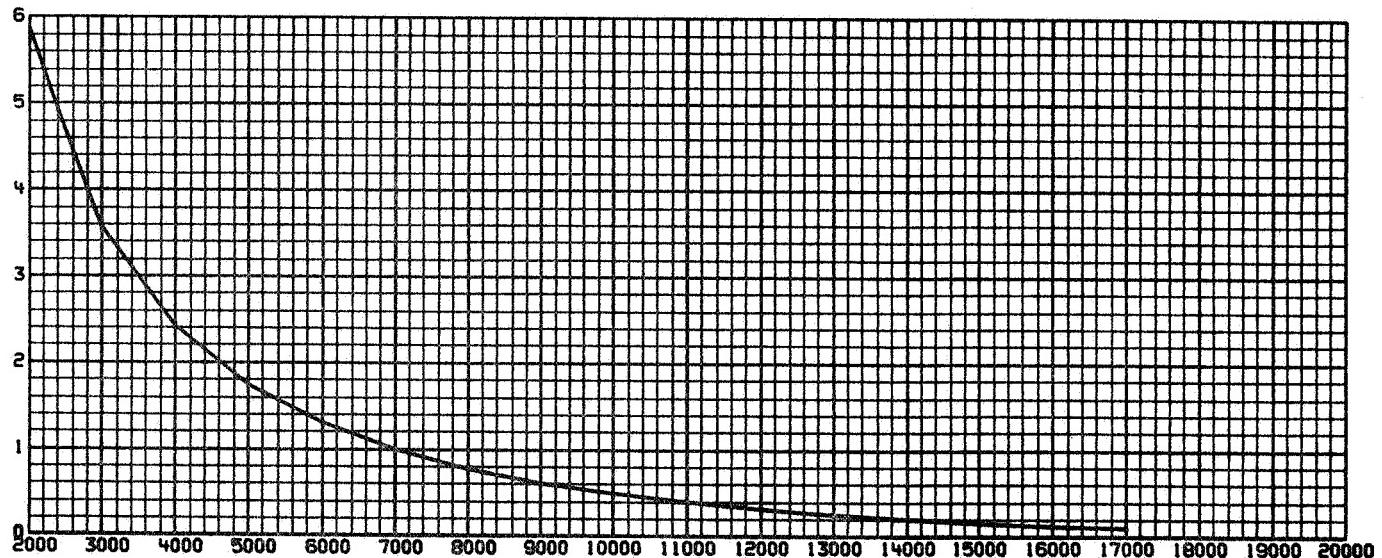
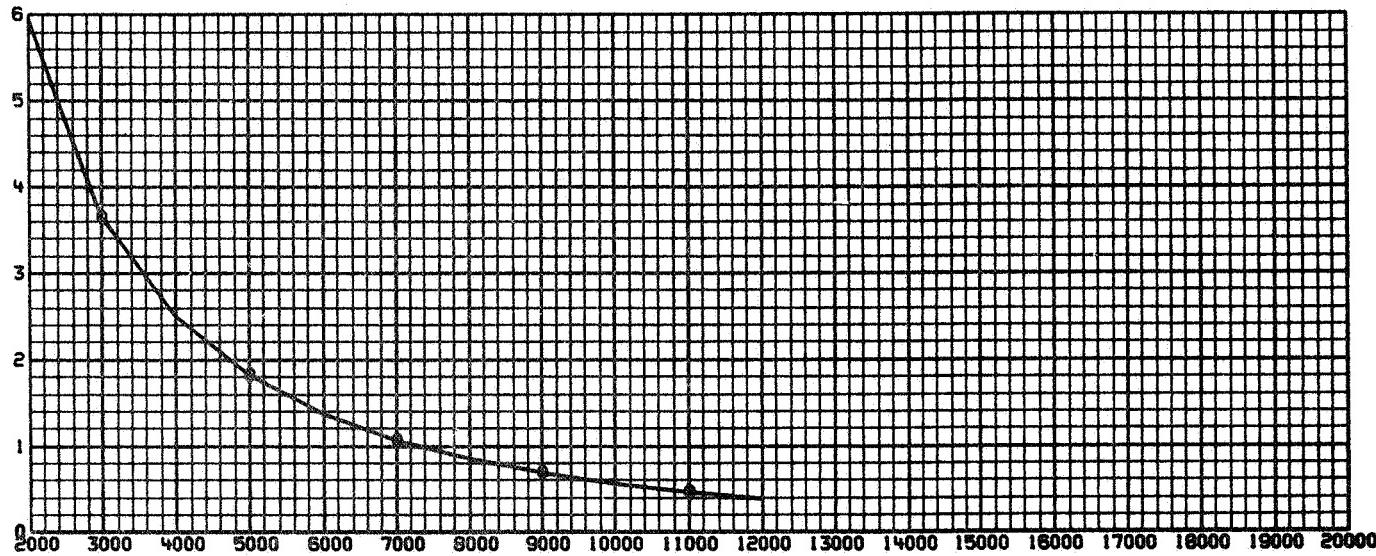


Figure 3-102

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-103

NOTE

**Offloaded propellant
in Mode 2 is not
a function of ΔV**

Figure 3-104

MODE 3

PAYOUT DELIVERED 47830 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE P/L ** REUSEABLE TUG
 • = FIXED PROPELLANT 47830 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
 □ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

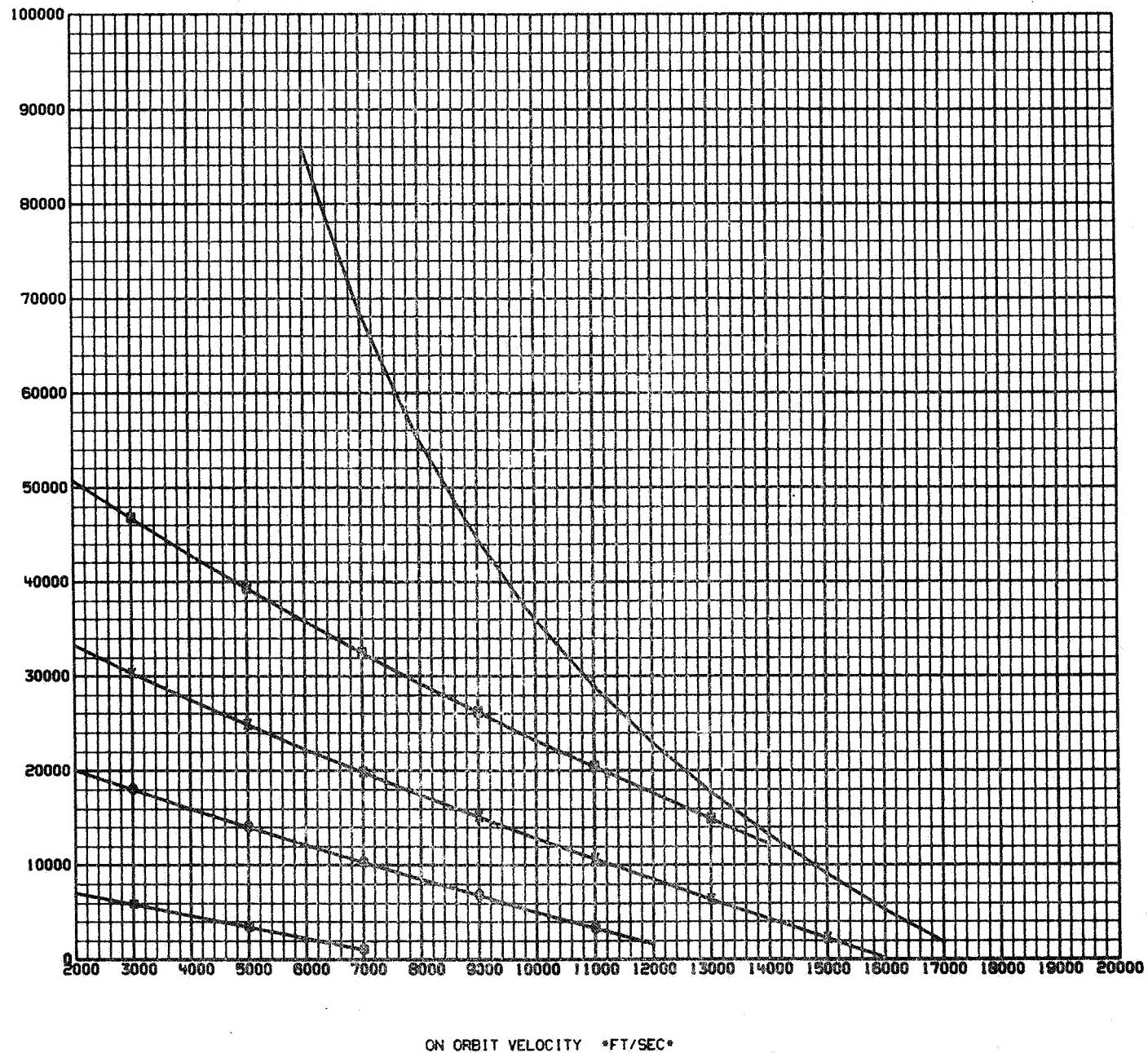
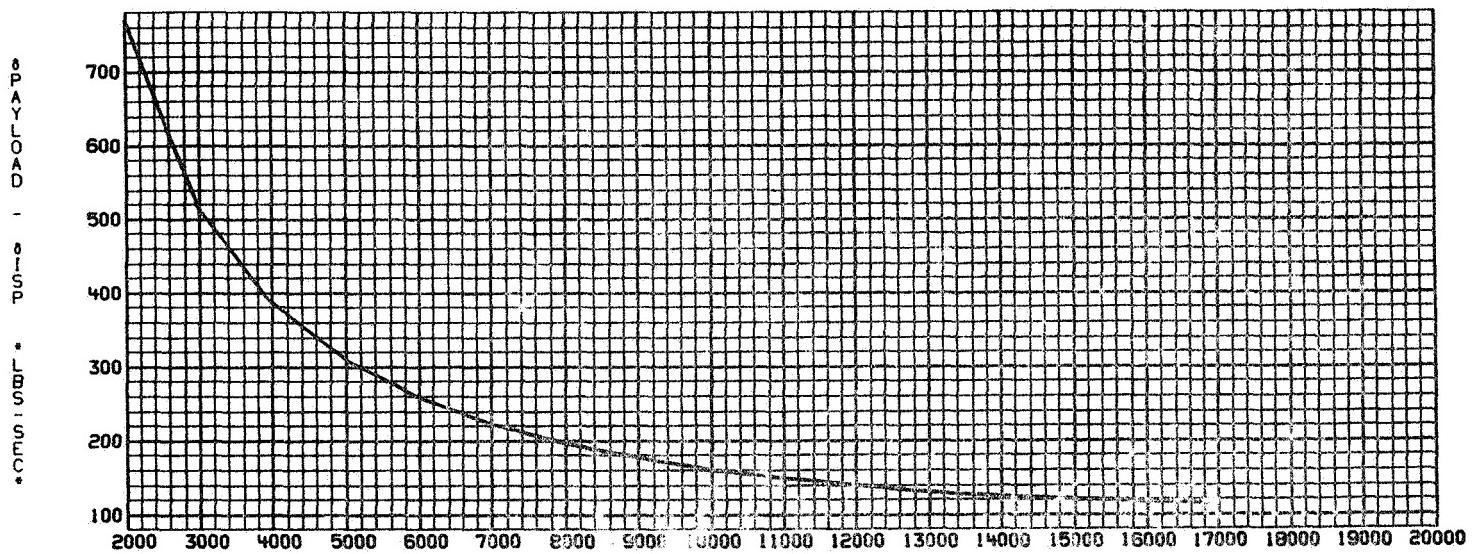


Figure 3-105

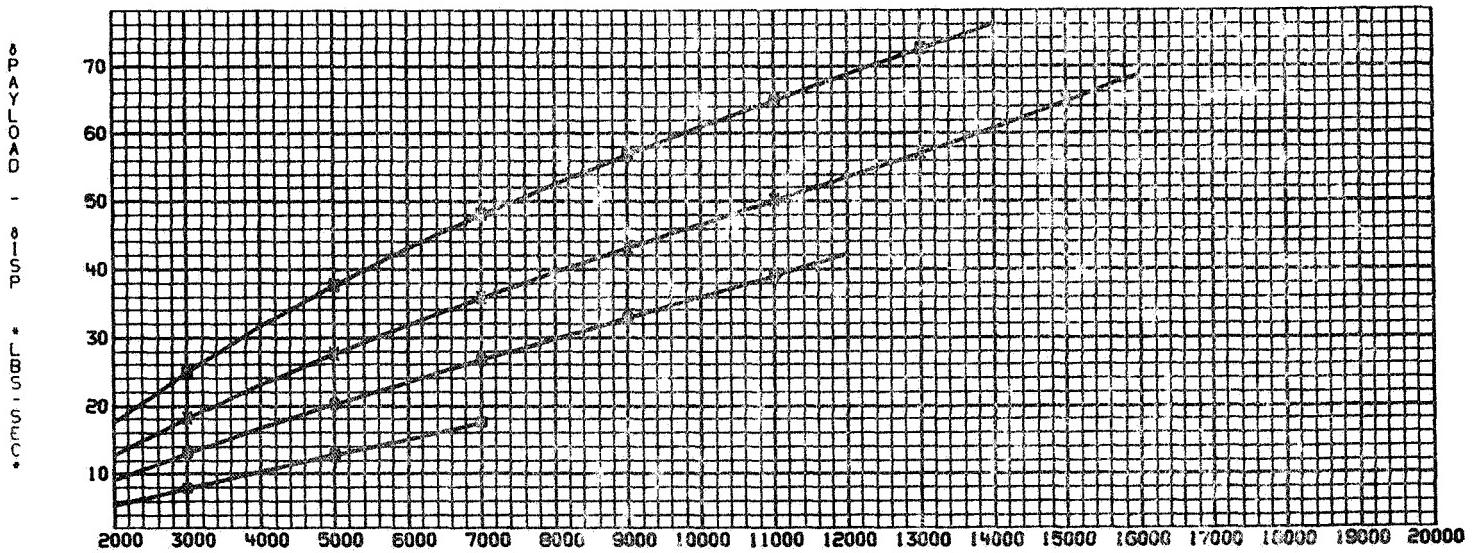
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.
× = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.



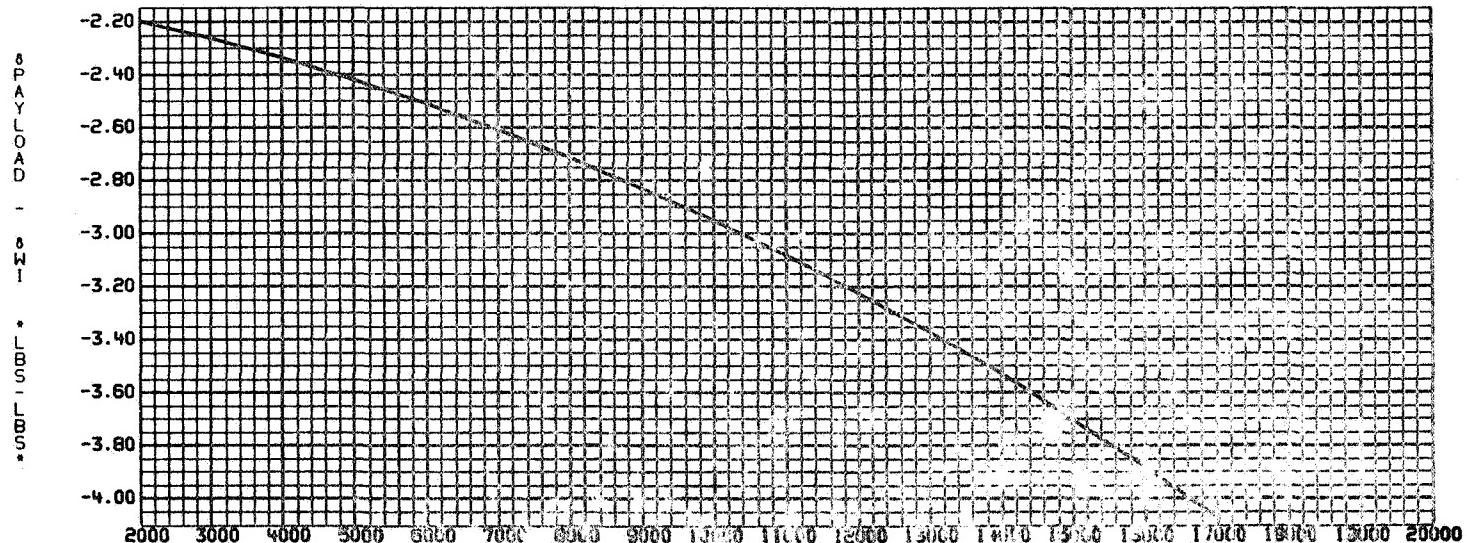
ON ORBIT VELOCITY *FT/SEC*

Figure 3-106

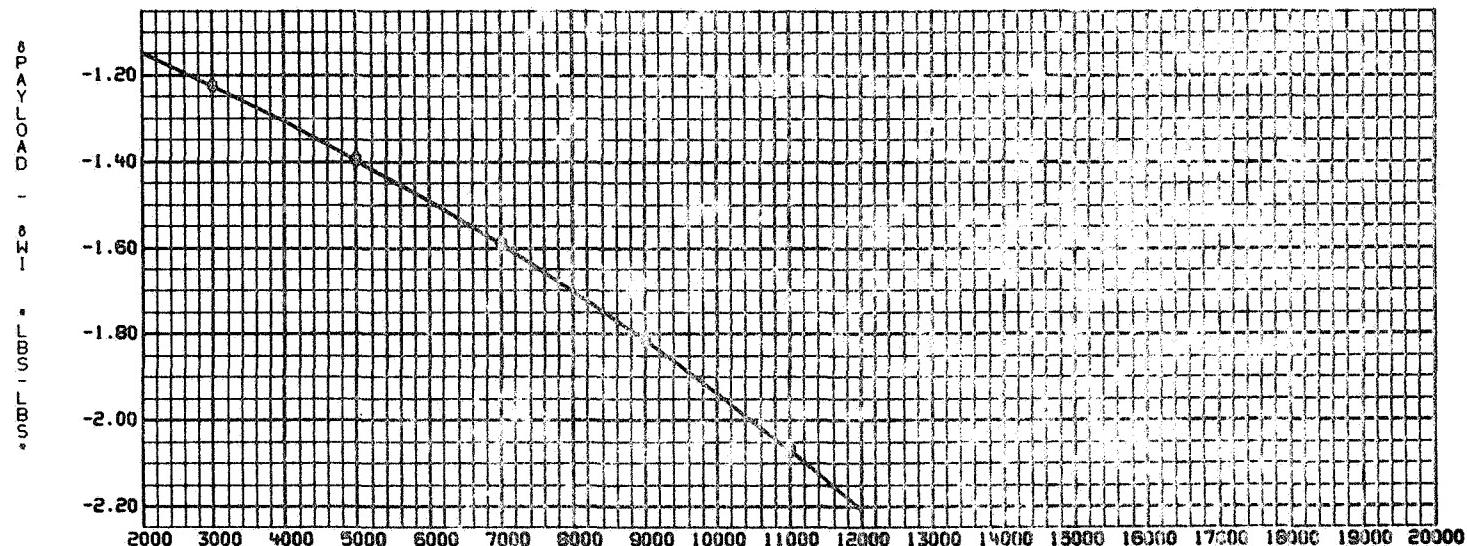
PAYOUT DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-107

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT

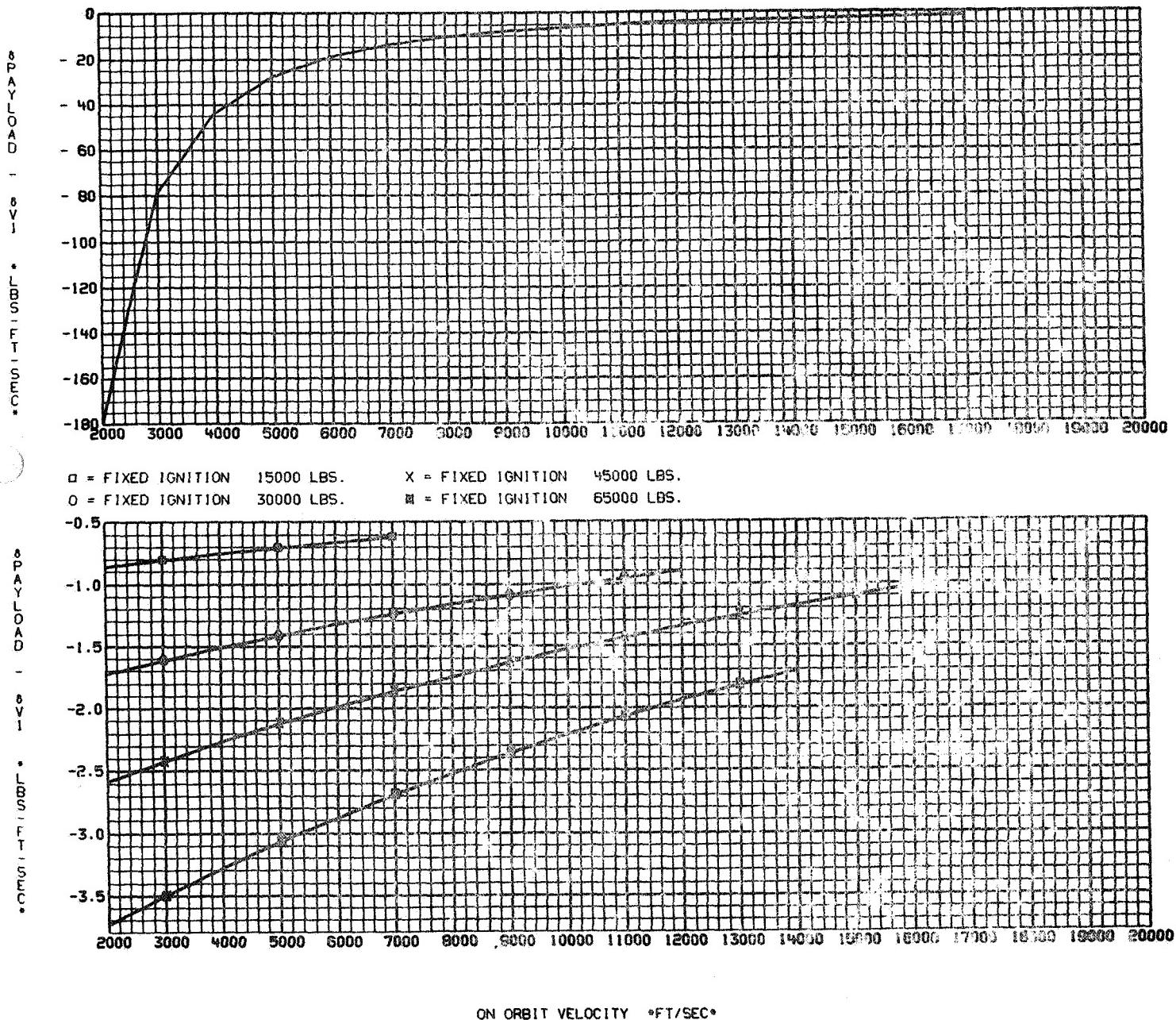


Figure 3-108

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT

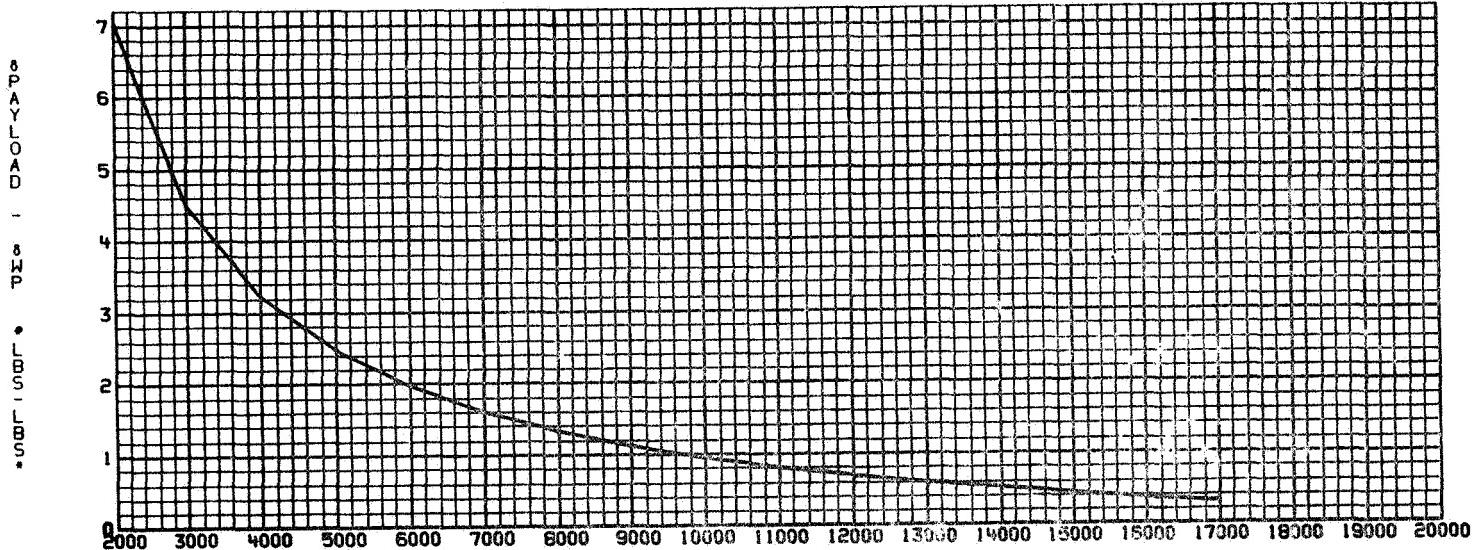
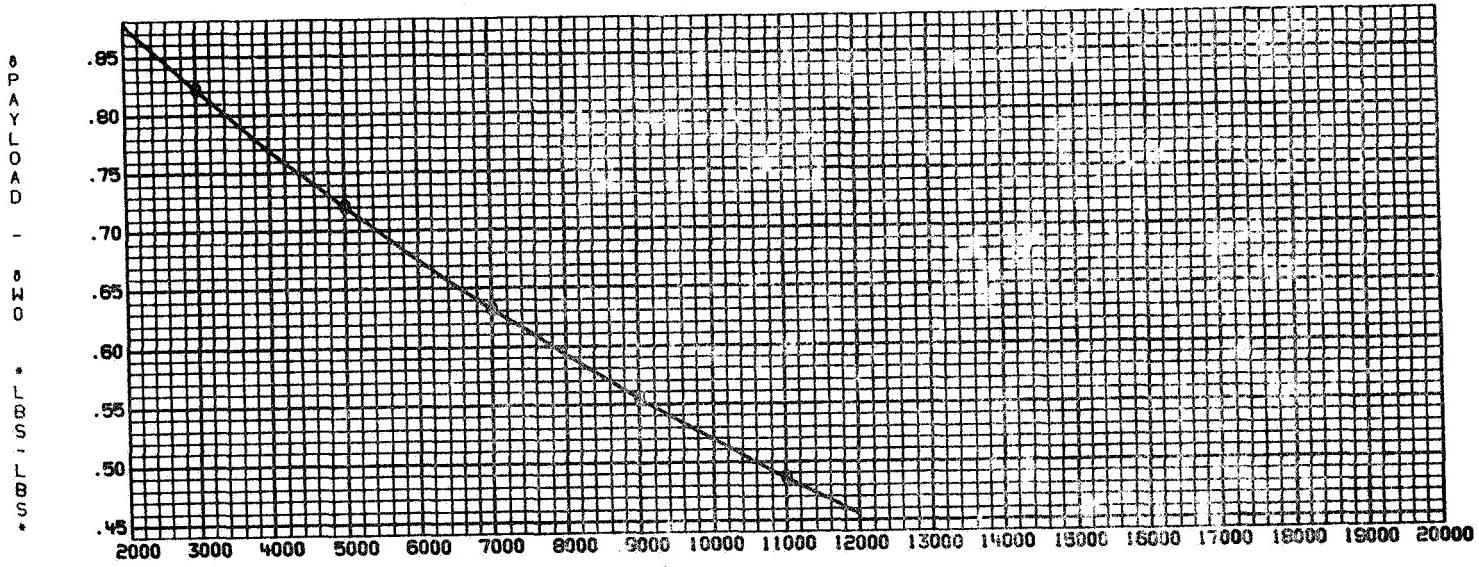


Figure 3-109

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY - FT/SEC*

Figure 3-110

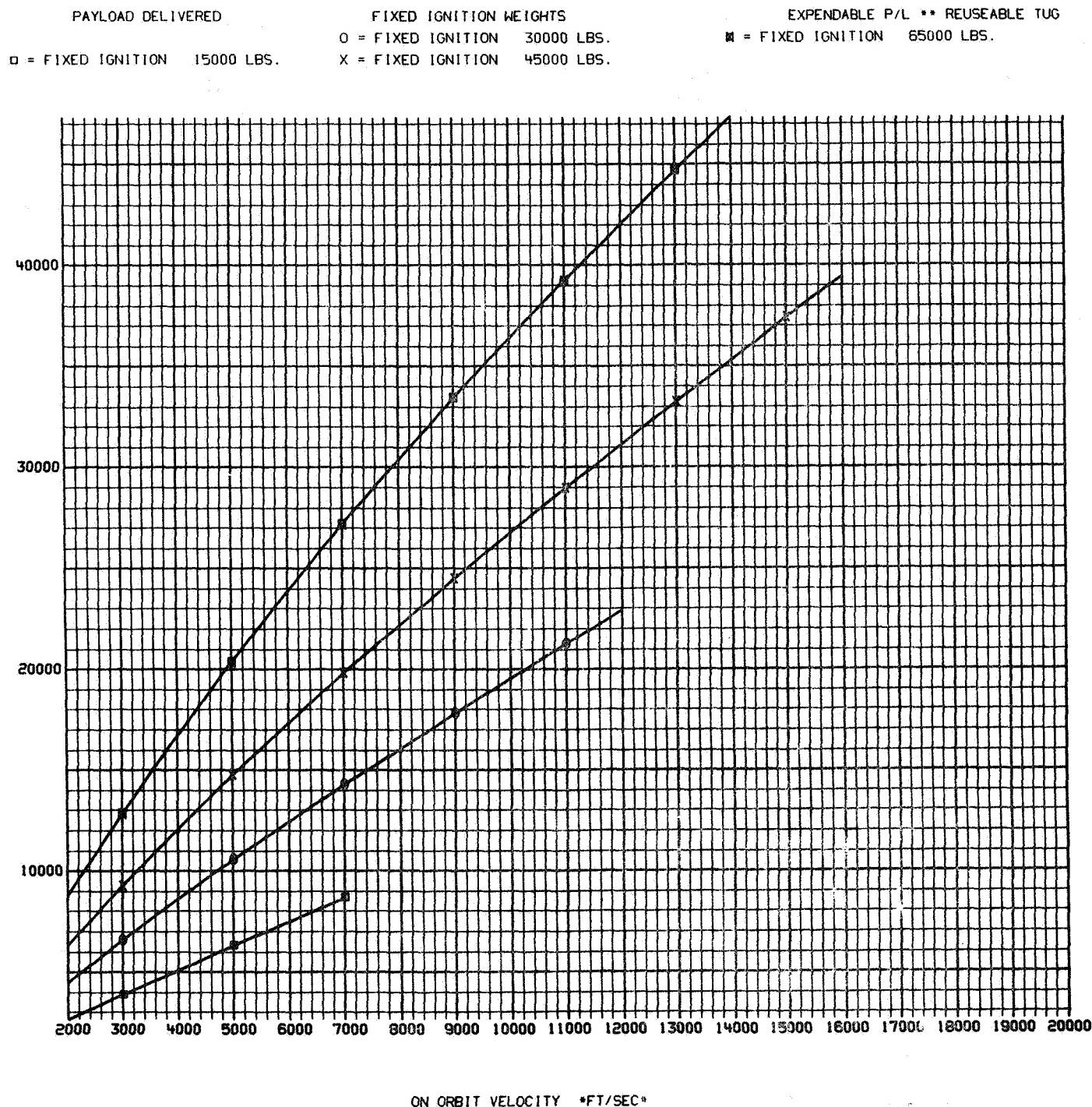
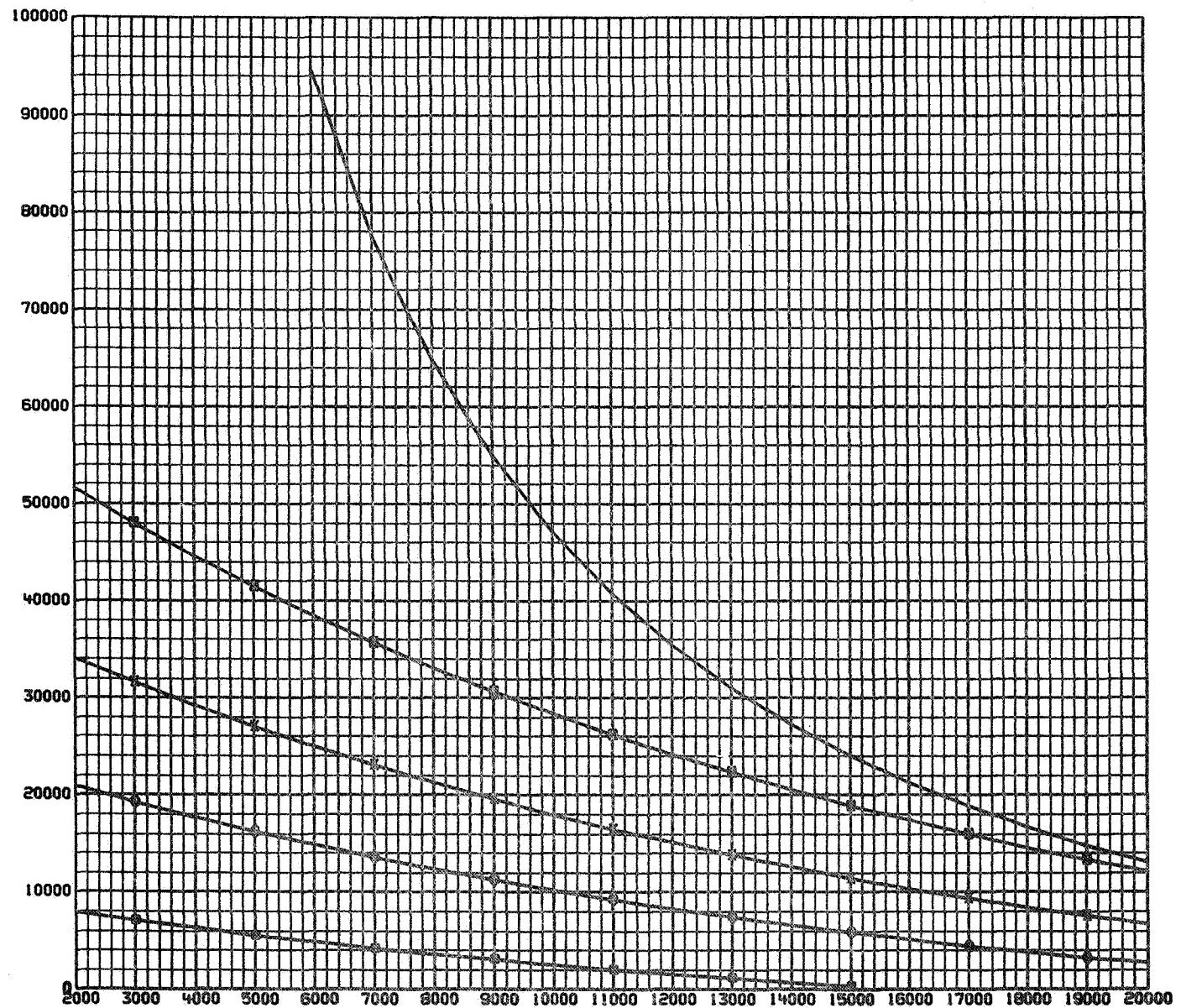


Figure 3-111

MODE 4

PAYOUT DELIVERED 47830 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE TUG AND P/L
 • = FIXED PROPELLANT 47830 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
 □ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.



ON CRASH VEHICLE 111-177520

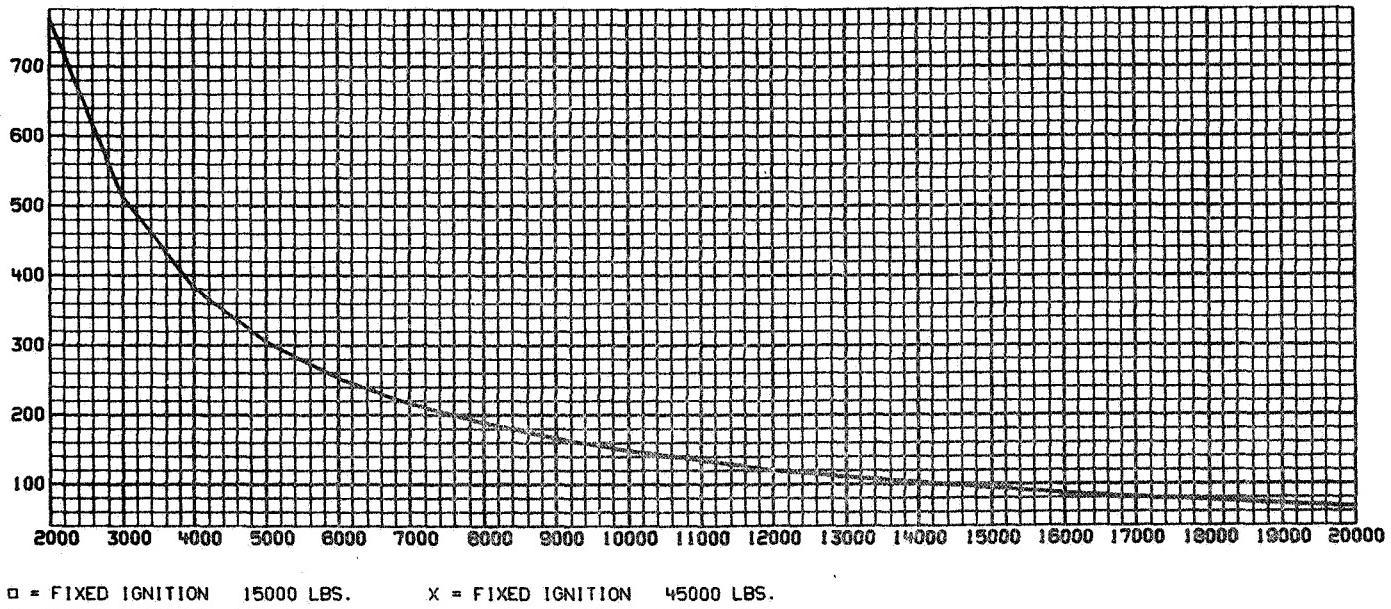
Figure 3-112

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

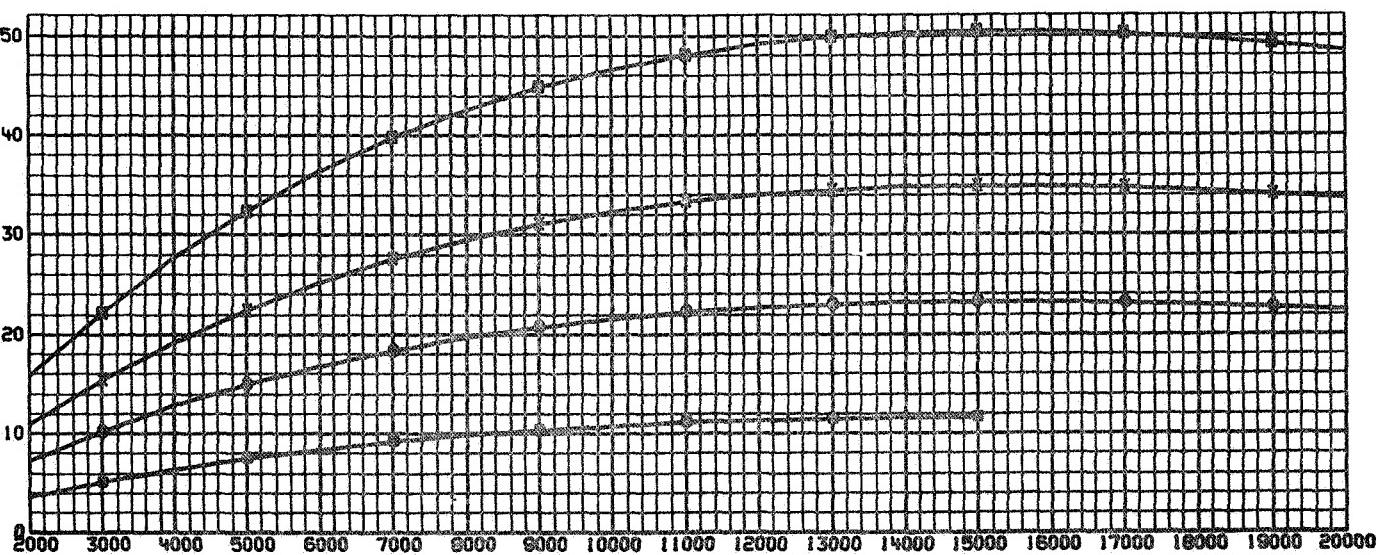
47830 LBS. FIXED PROPELLANT WEIGHT

PAYLOAD -
SISP
* LBS SEC *



□ = FIXED IGNITION 15000 LBS. × = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.

PAYLOAD -
SISP
* LBS SEC *



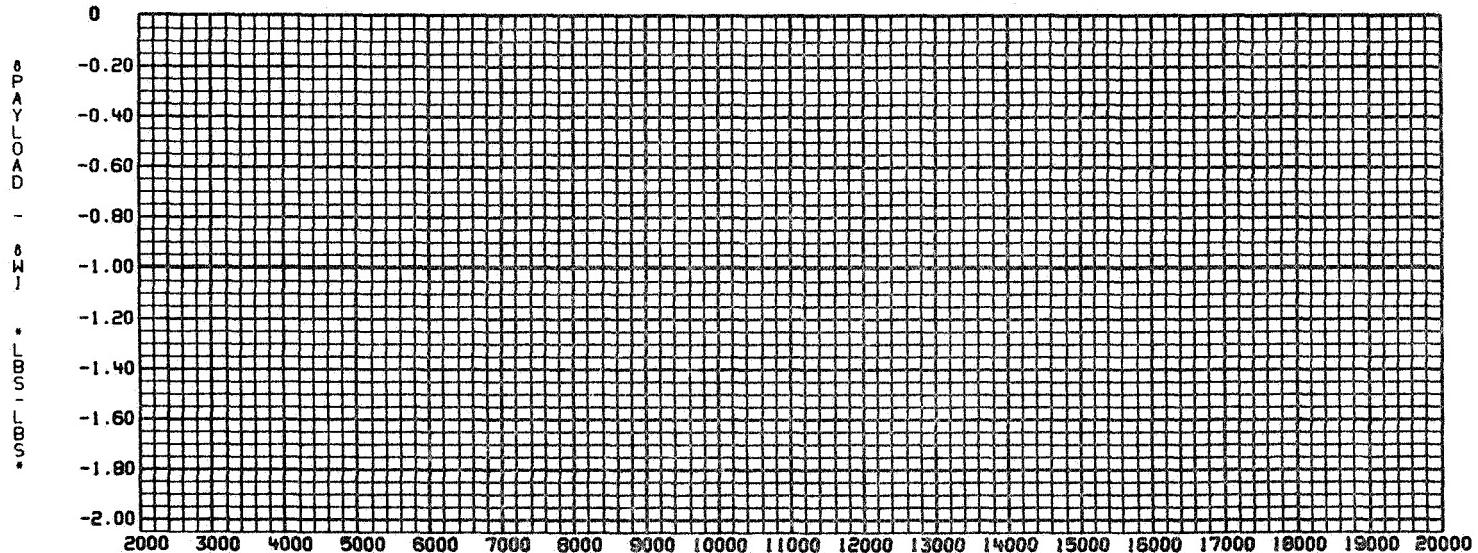
ON ORBIT VELOCITY *FT/SEC*

Figure 3-113

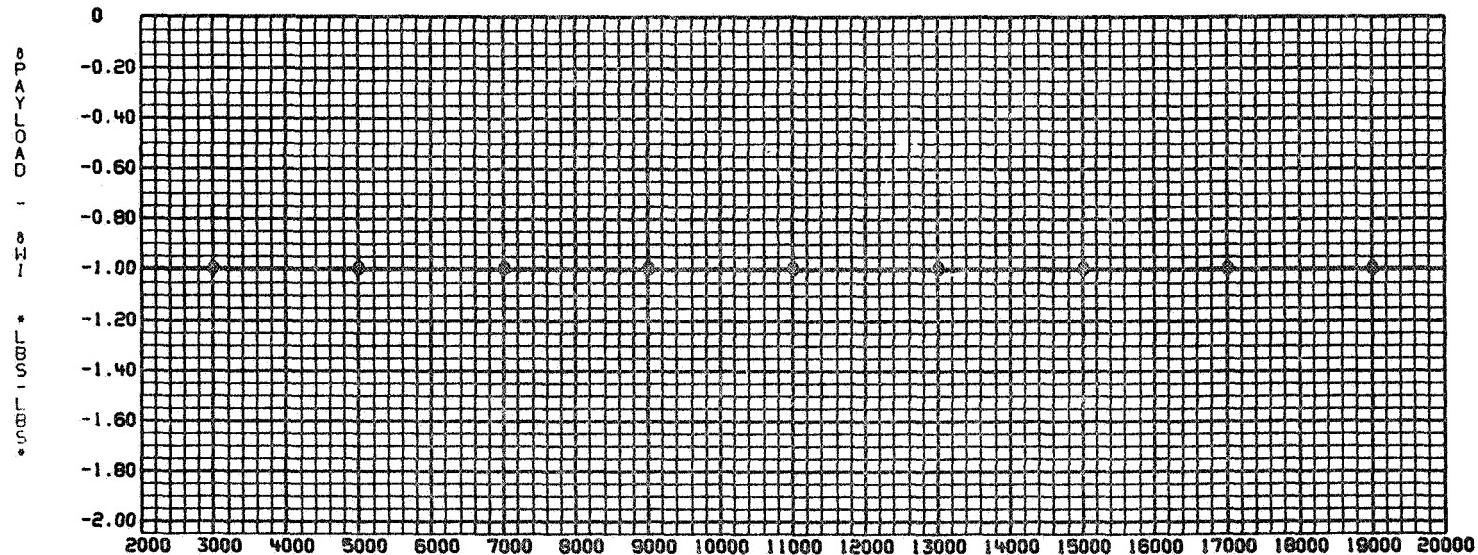
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-114

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT

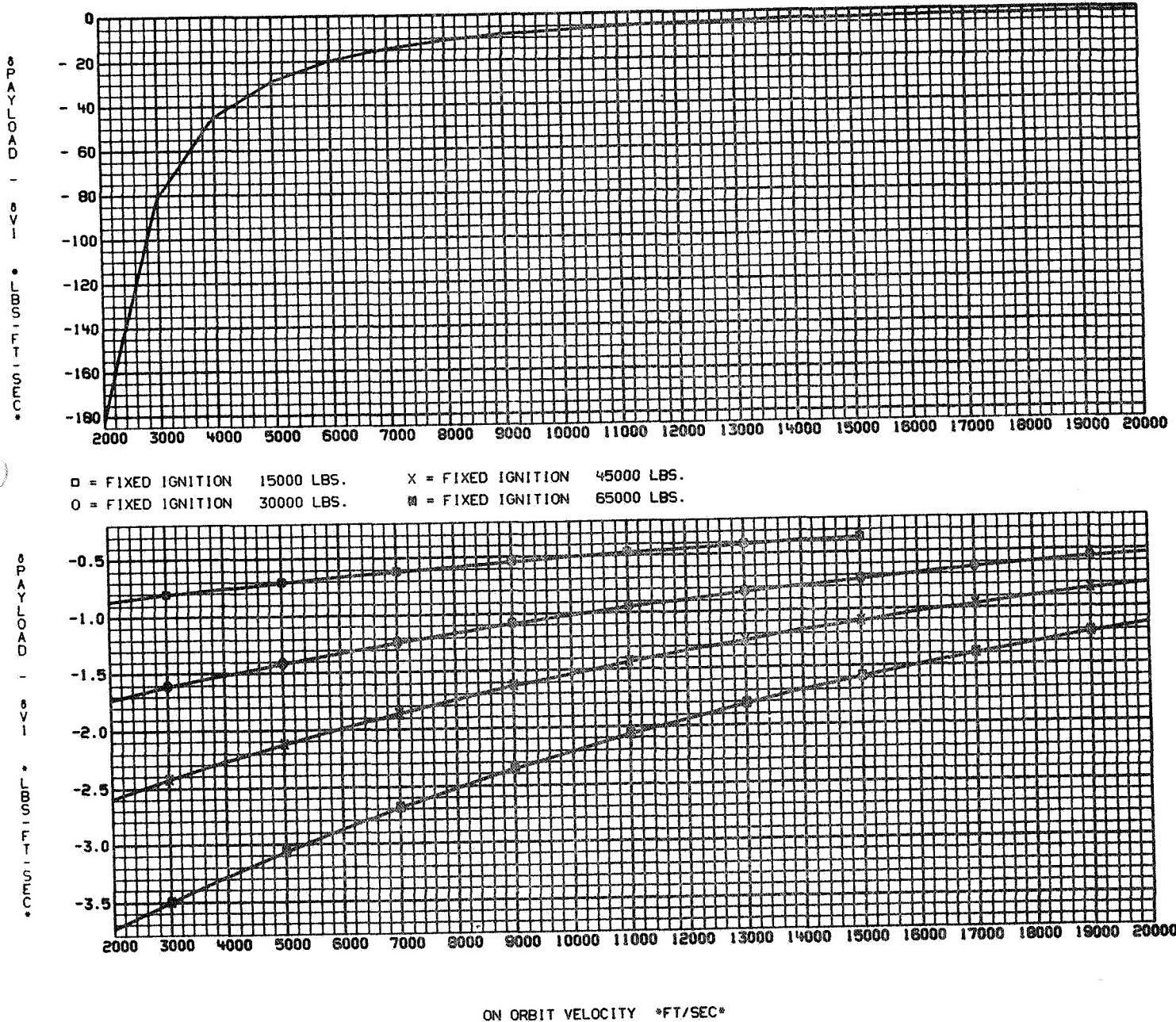


Figure 3-115

PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

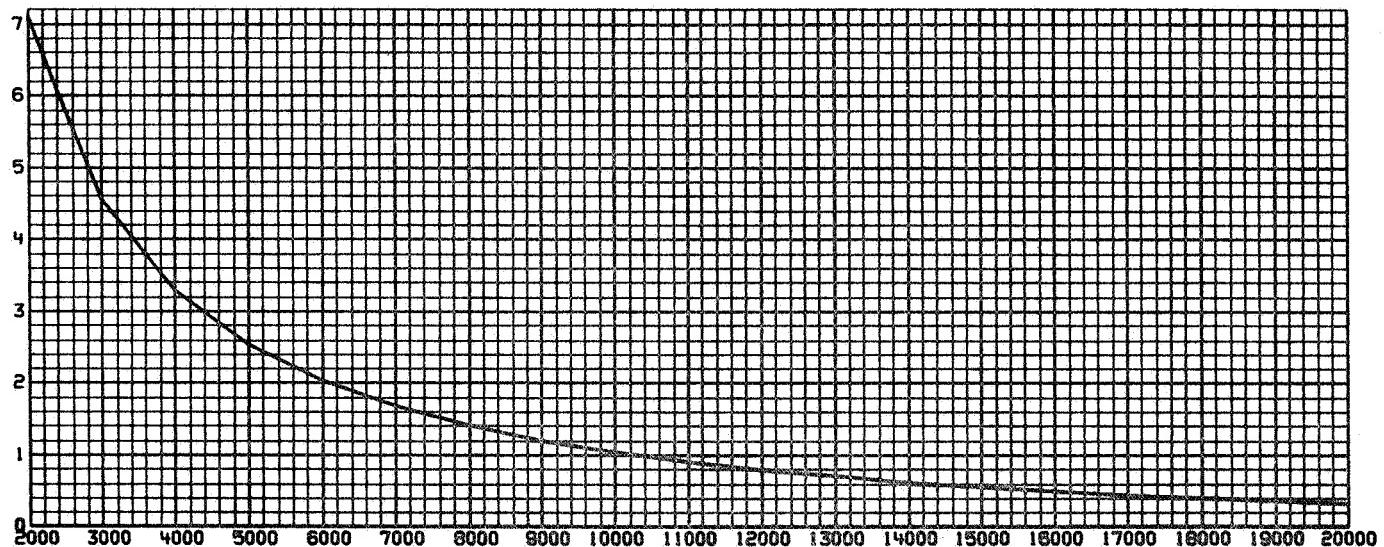
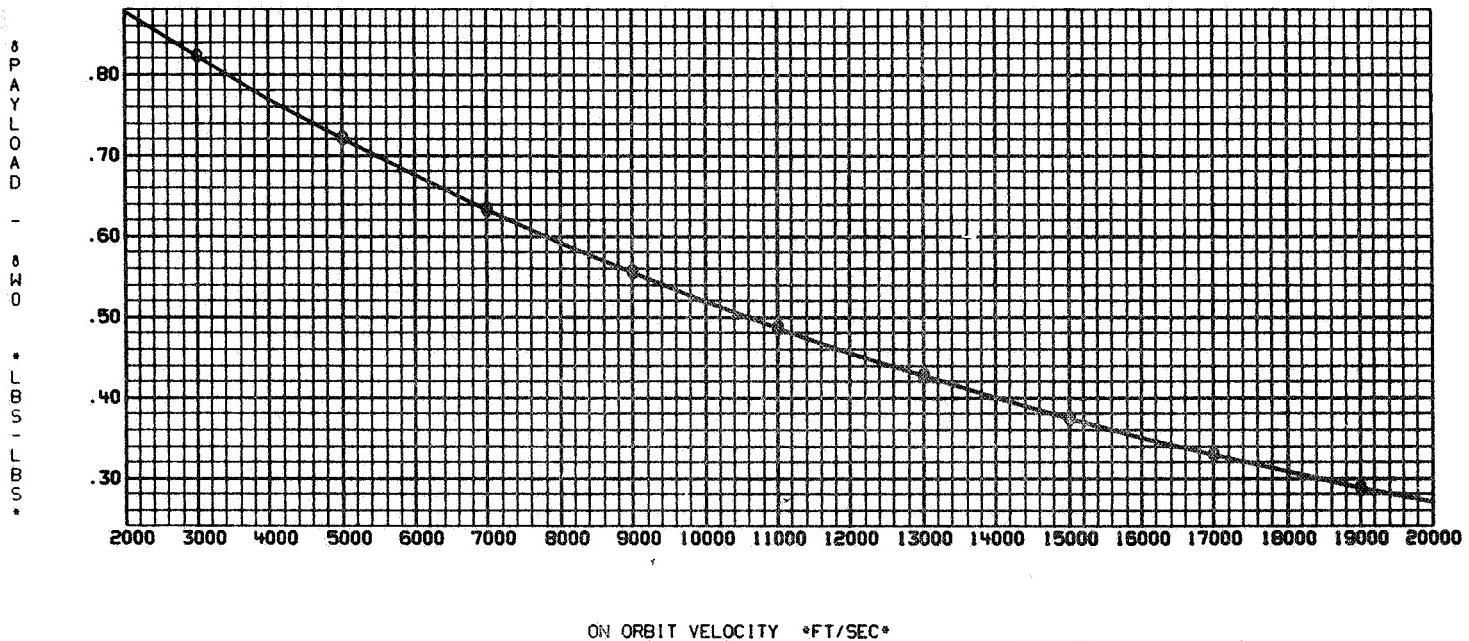


Figure 3-116

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-117

PAYOUT DELIVERED

FIXED IGNITION WEIGHTS
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

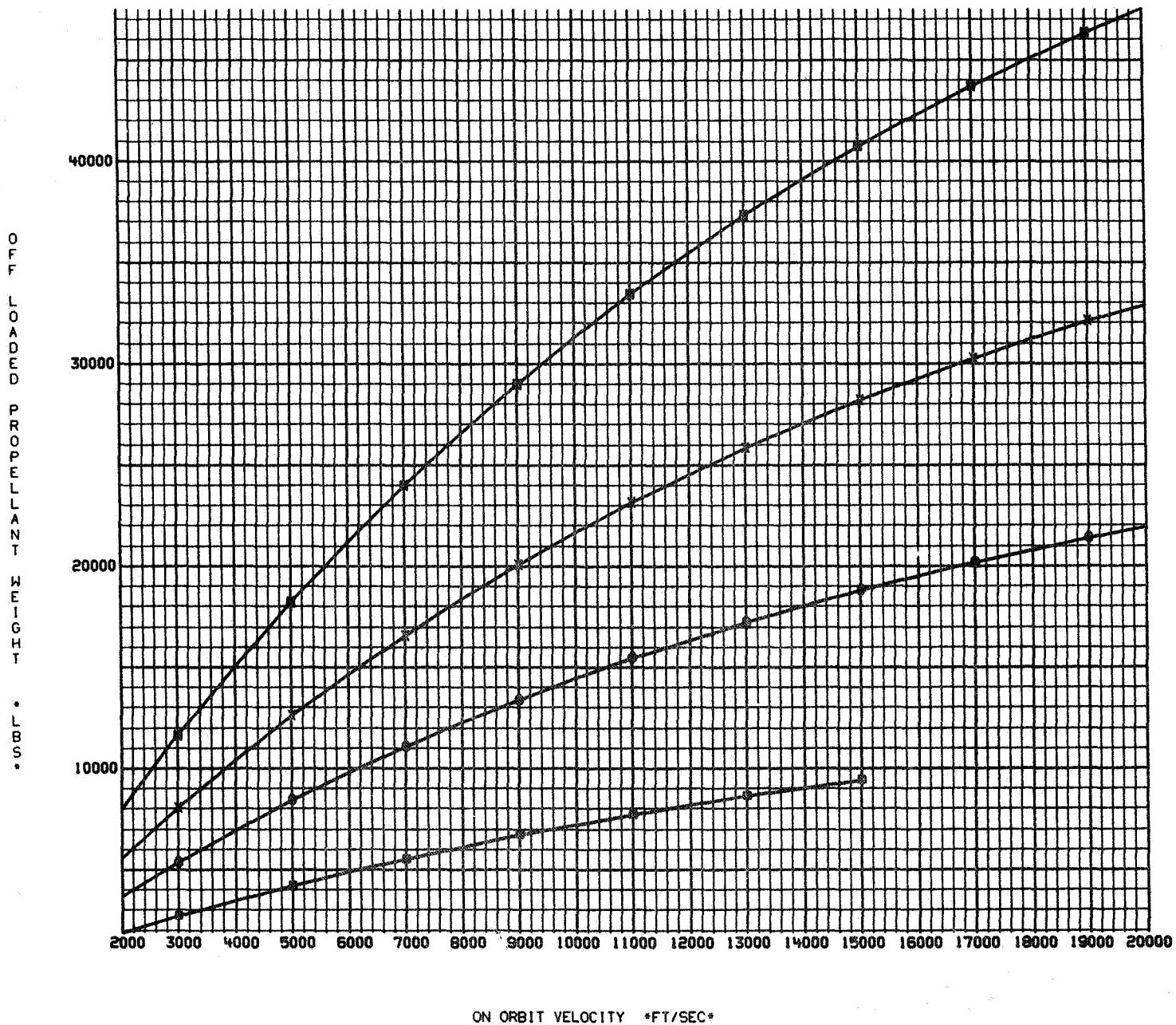


Figure 3-118

MODE 1

PAYOUT RETURNED	51994 LBS. FIXED PROPELLANT WEIGHT	ROUND TRIPPED P/L CAPABILITY
<input checked="" type="checkbox"/> = FIXED PROPELLANT 51994 LBS.	O = FIXED IGNITION 30000 LBS.	<input checked="" type="checkbox"/> = FIXED IGNITION 65000 LBS.
<input type="checkbox"/> = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

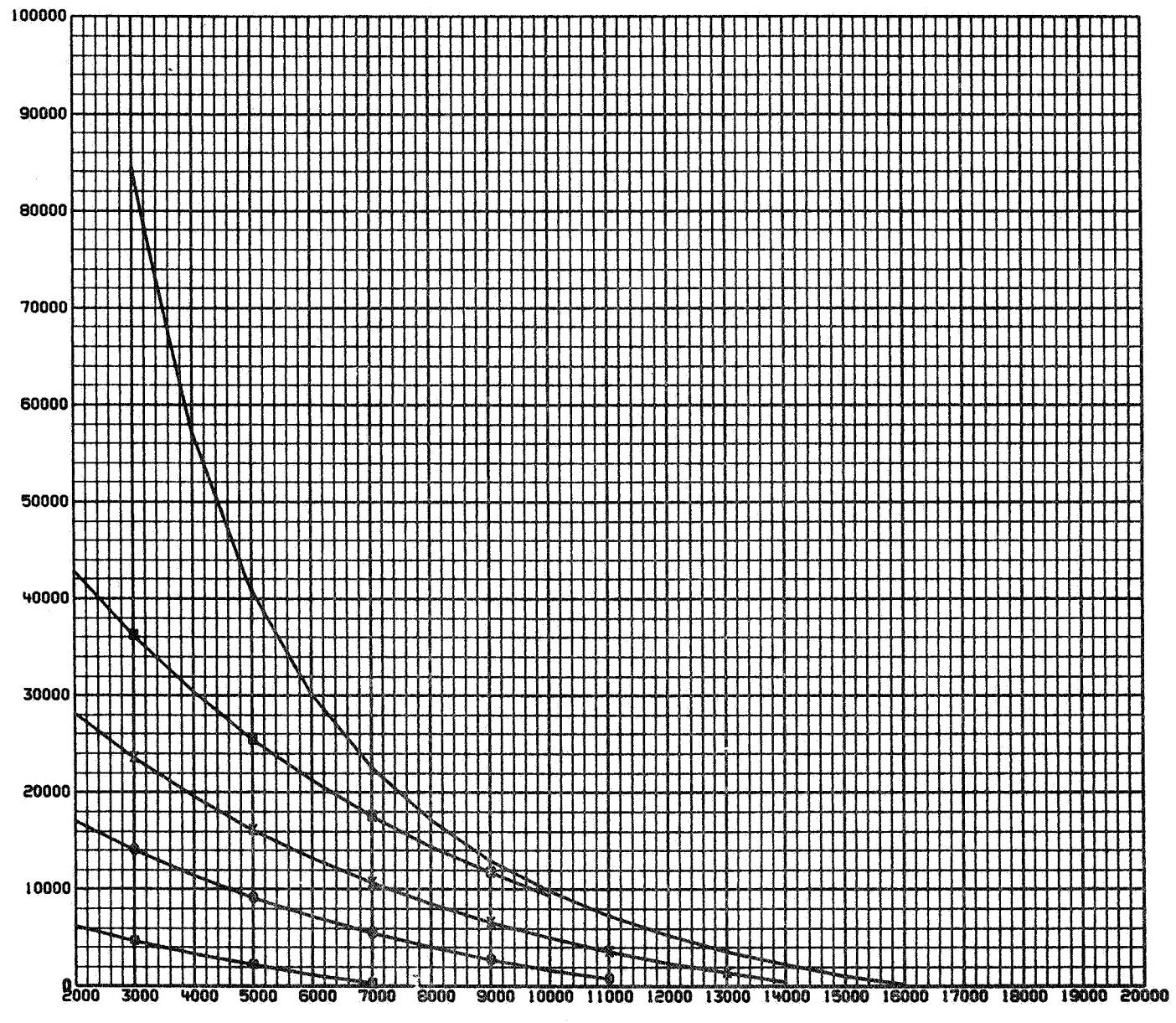


Figure 3-119

PAYLOAD RETURNED
ROUND TRIPPED P/L CAPABILITY
51994 LBS. FIXED PROPELLANT WEIGHT

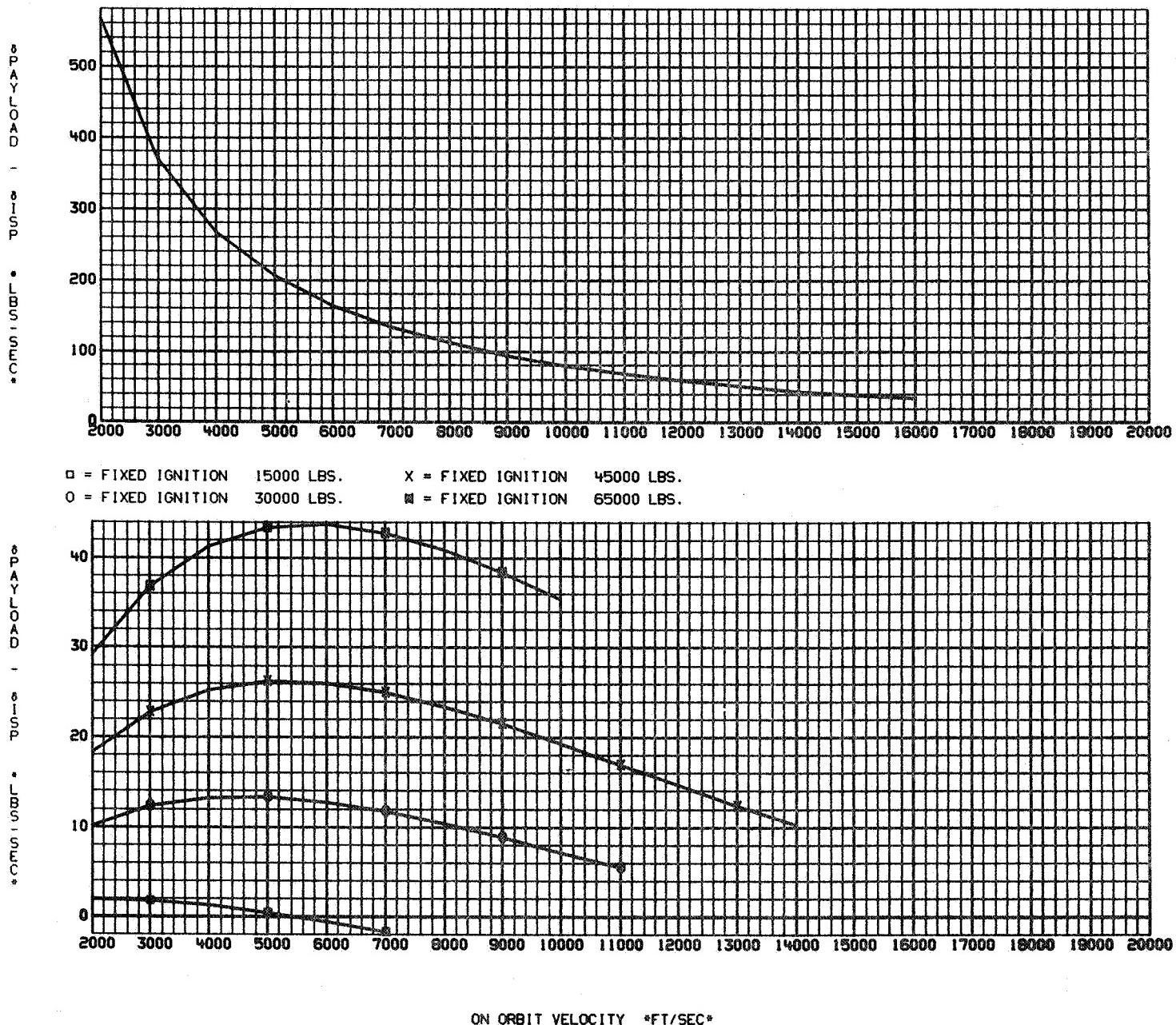
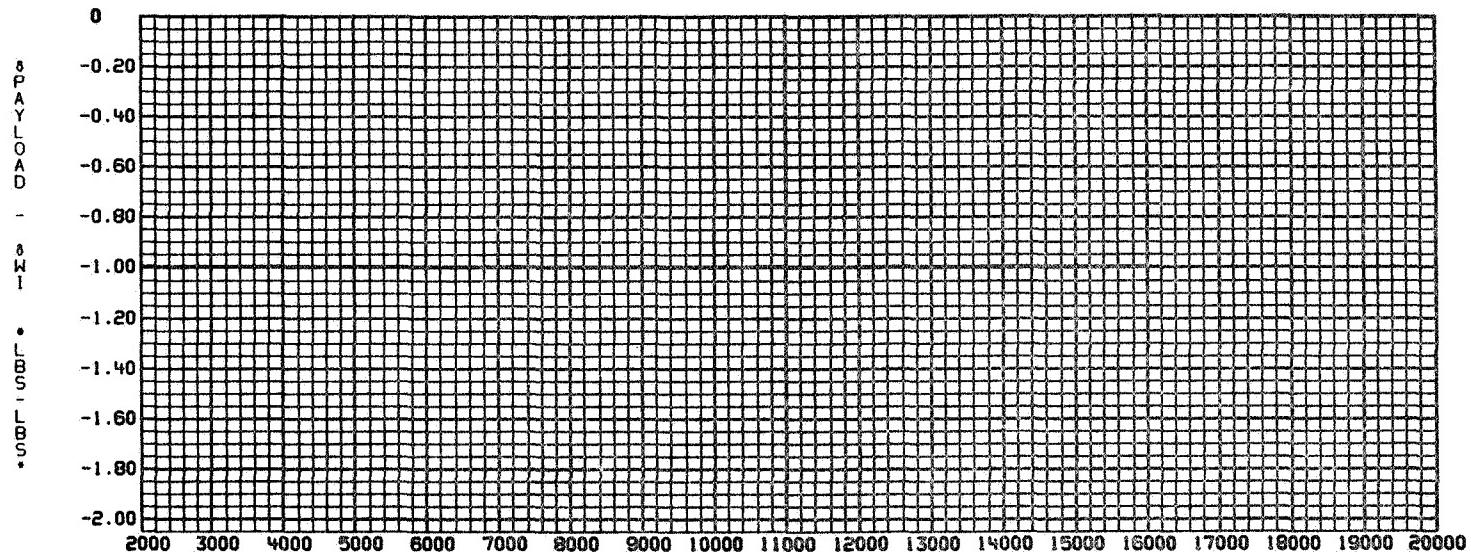


Figure 3-120

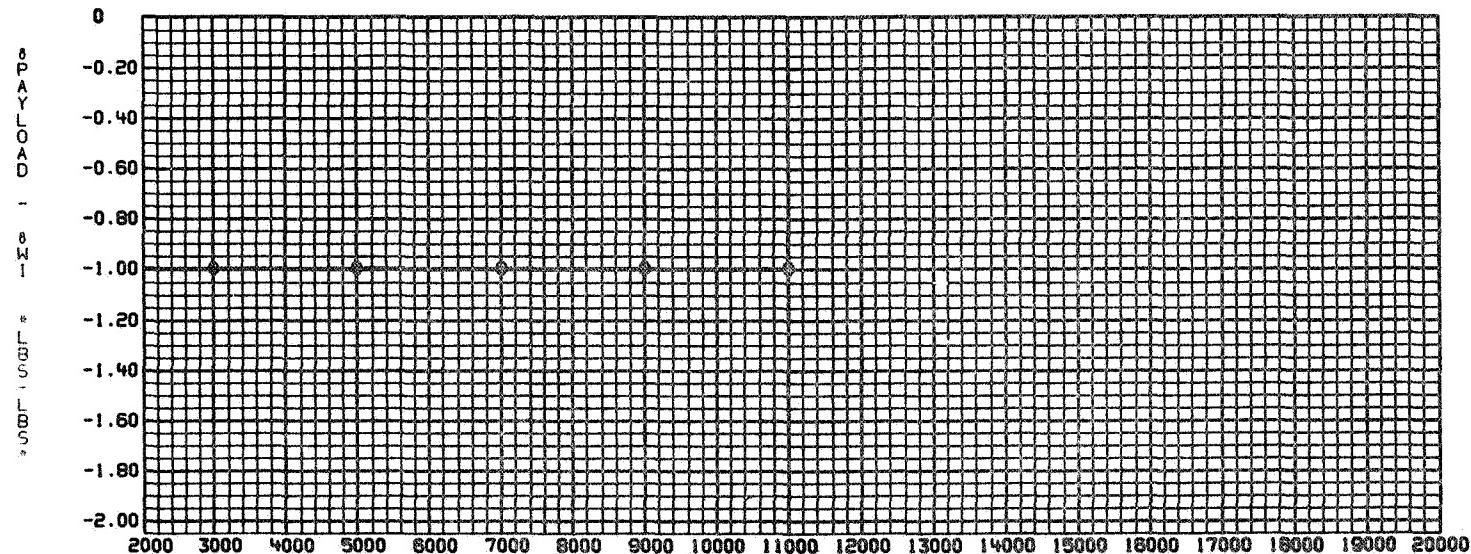
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



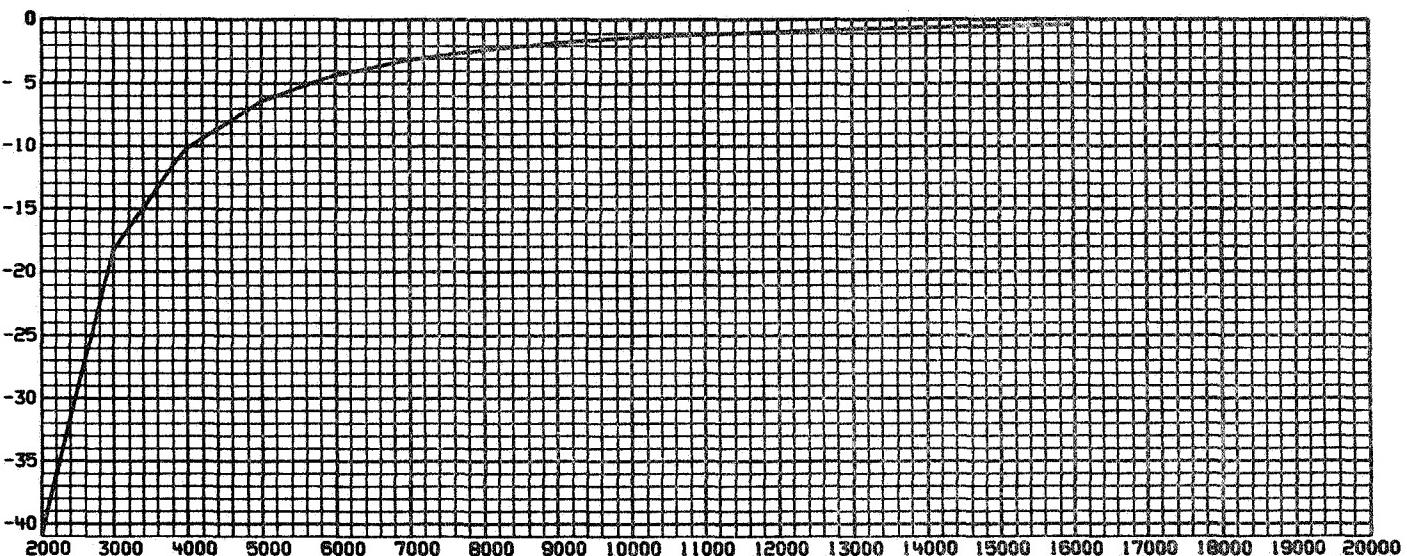
ON ORBIT VELOCITY *FT/SEC*

Figure 3-121

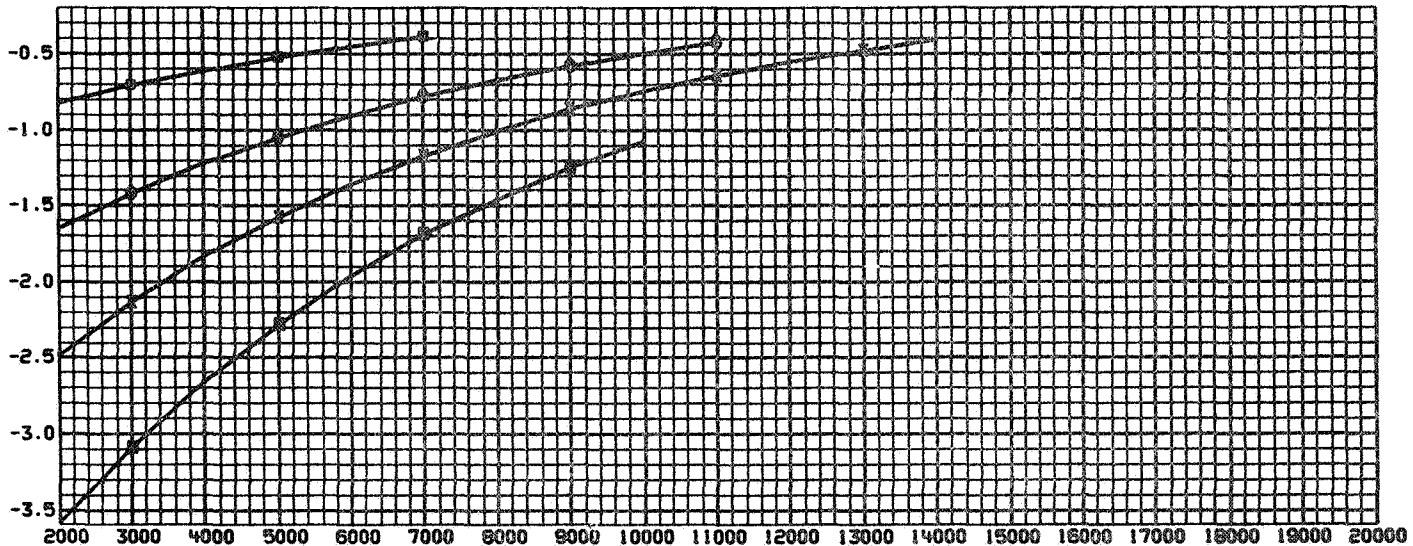
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. △ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-122

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

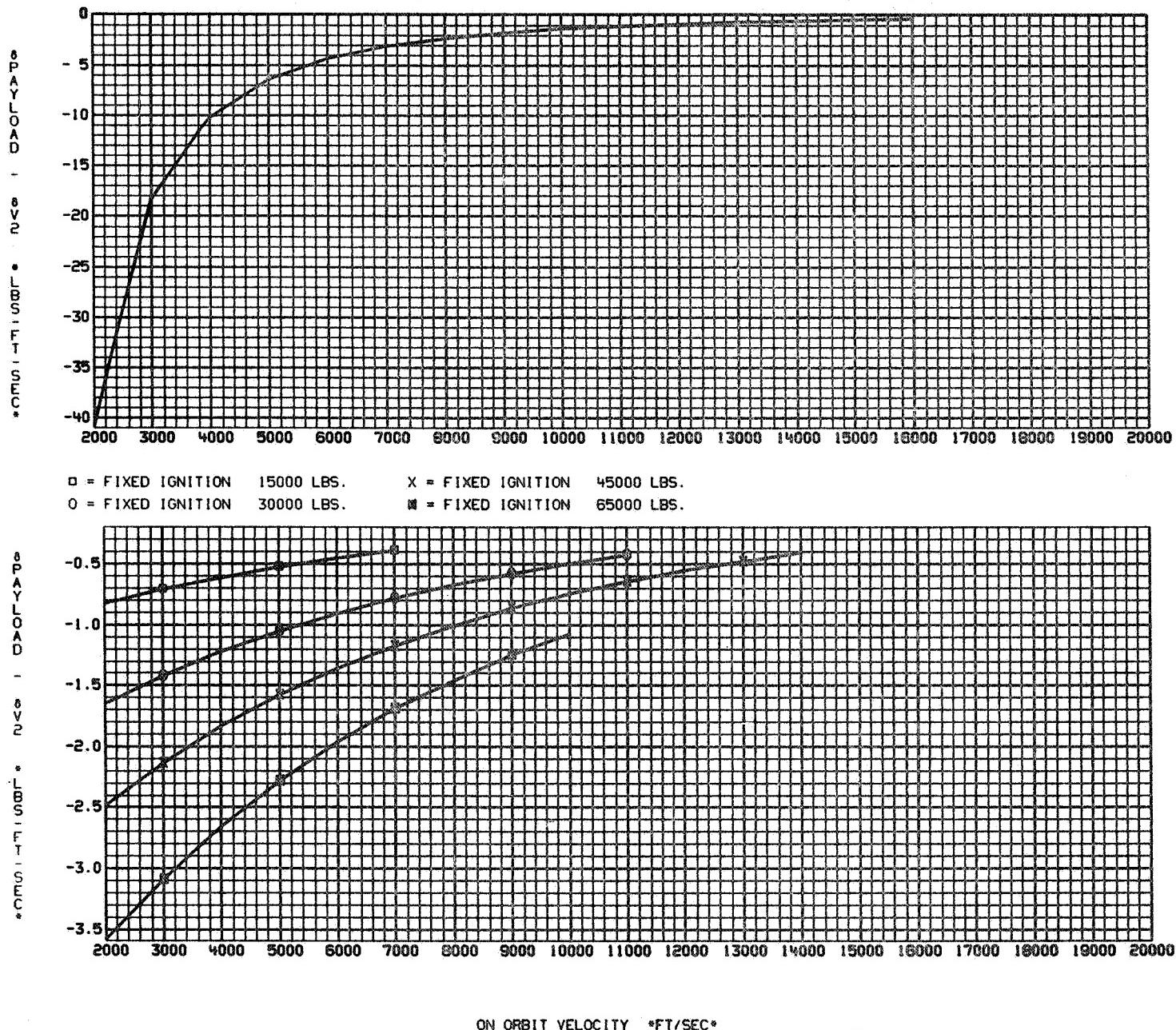


Figure 3-123

PAYLOAD DELIVERED
51994 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

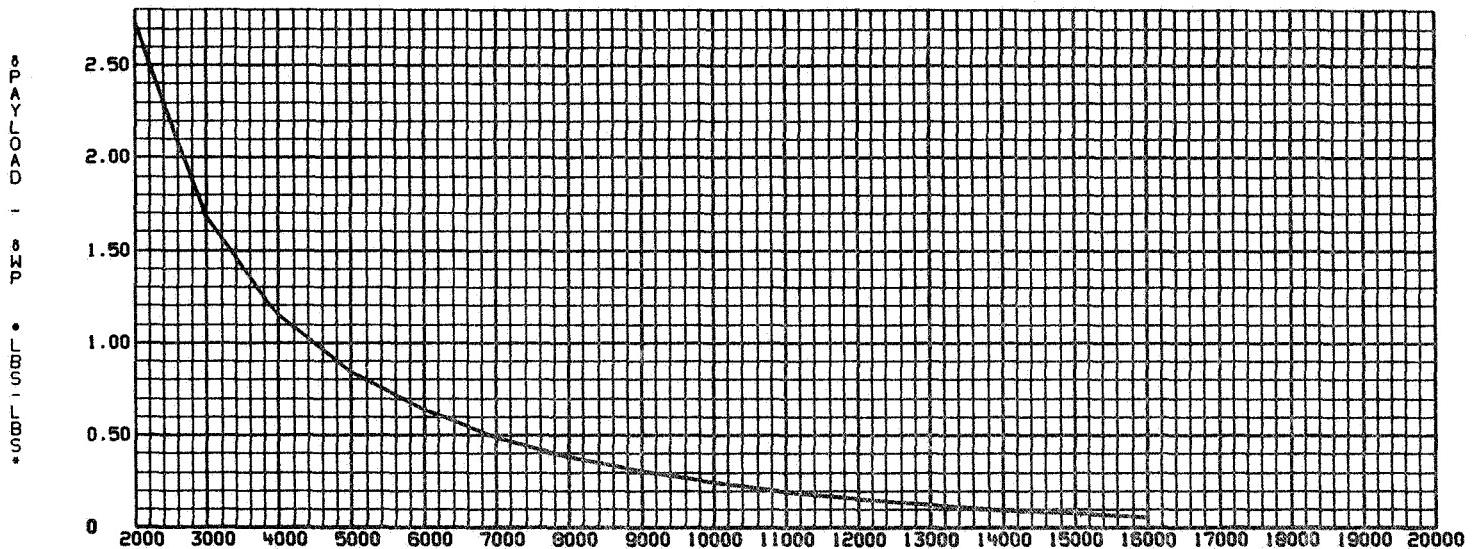
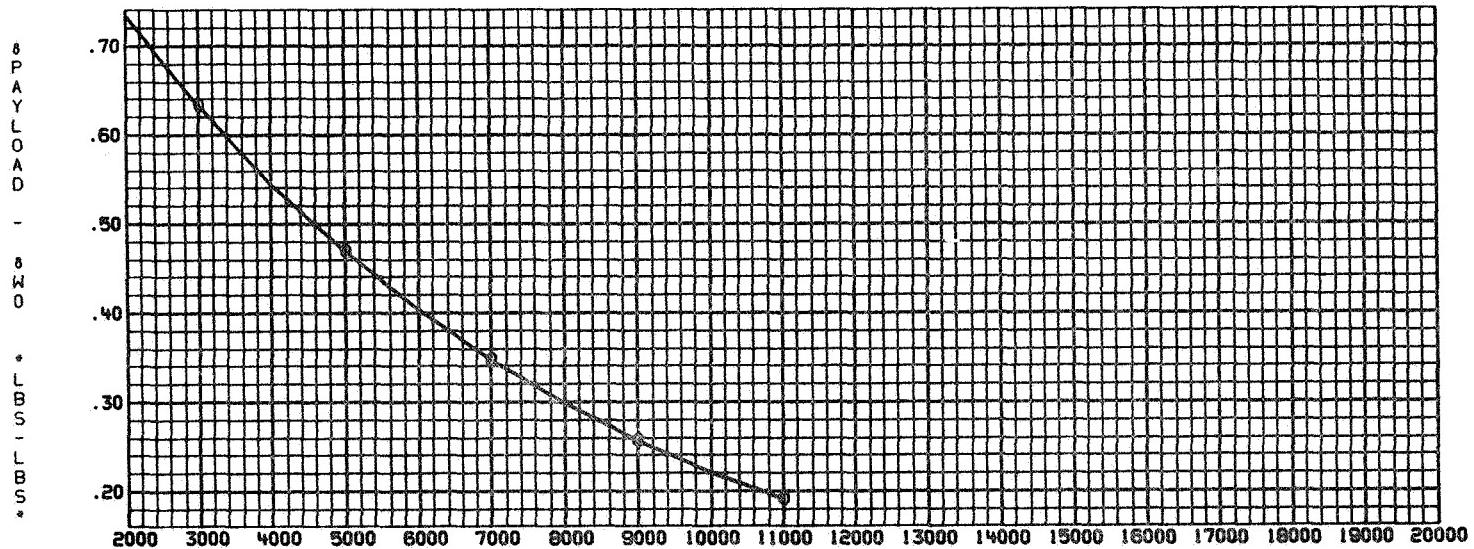


Figure 3-124

ALL FIXED IGNITION WEIGHTS



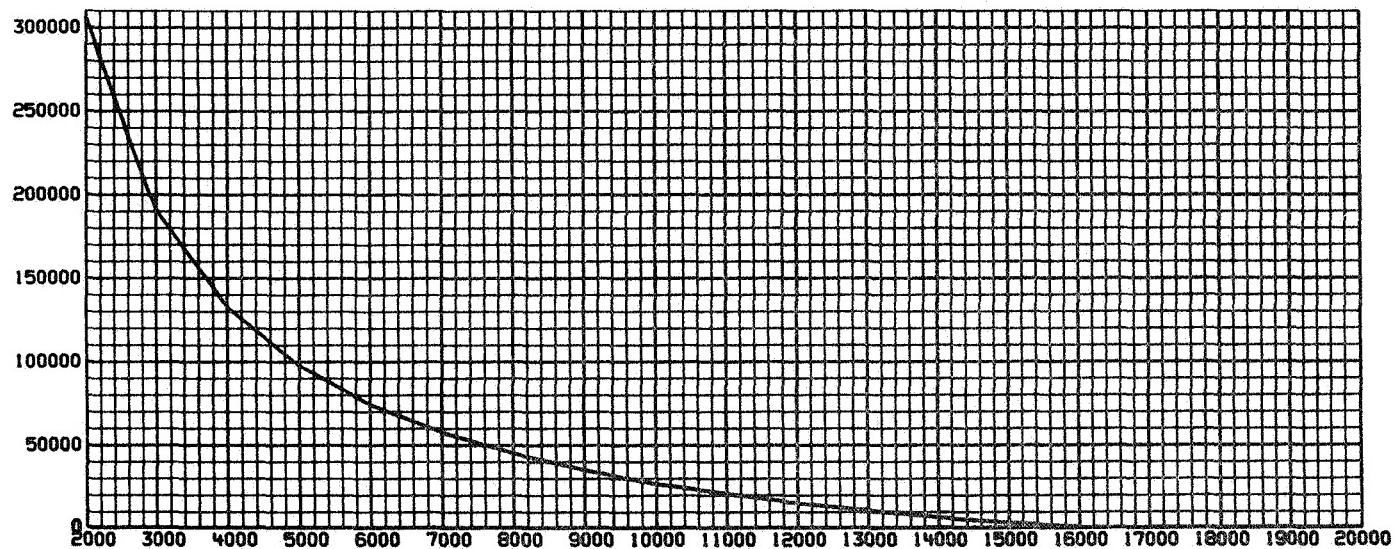
ON ORBIT VELOCITY *FT/SEC*

Figure 3-125

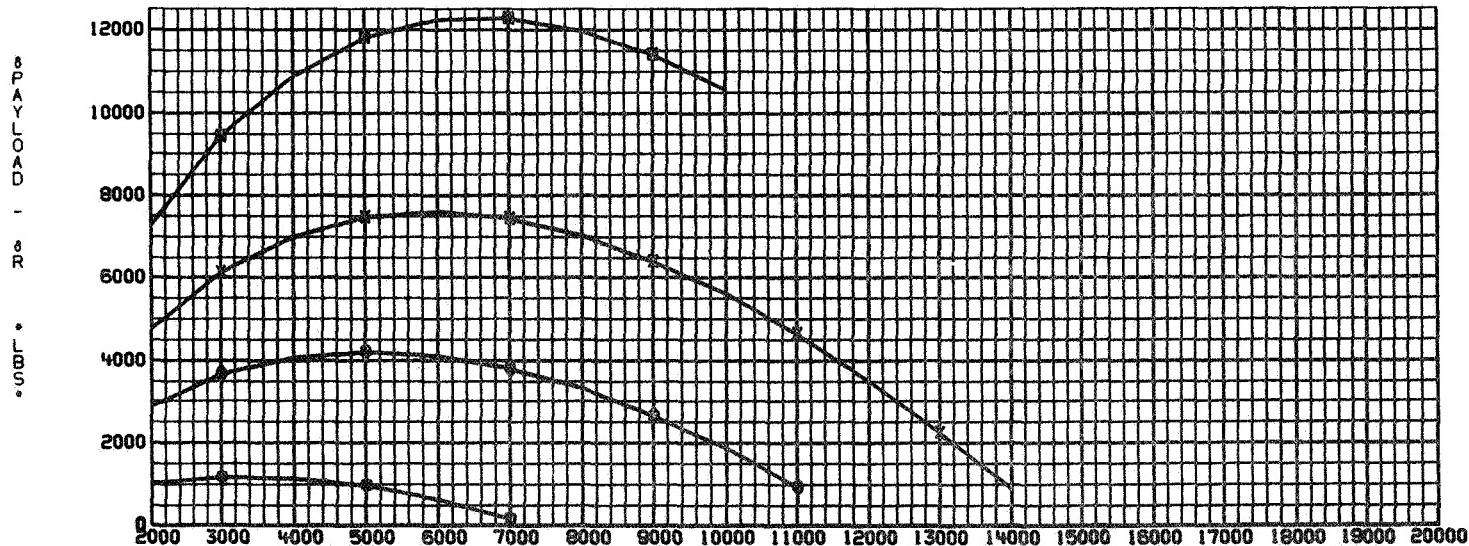
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-126

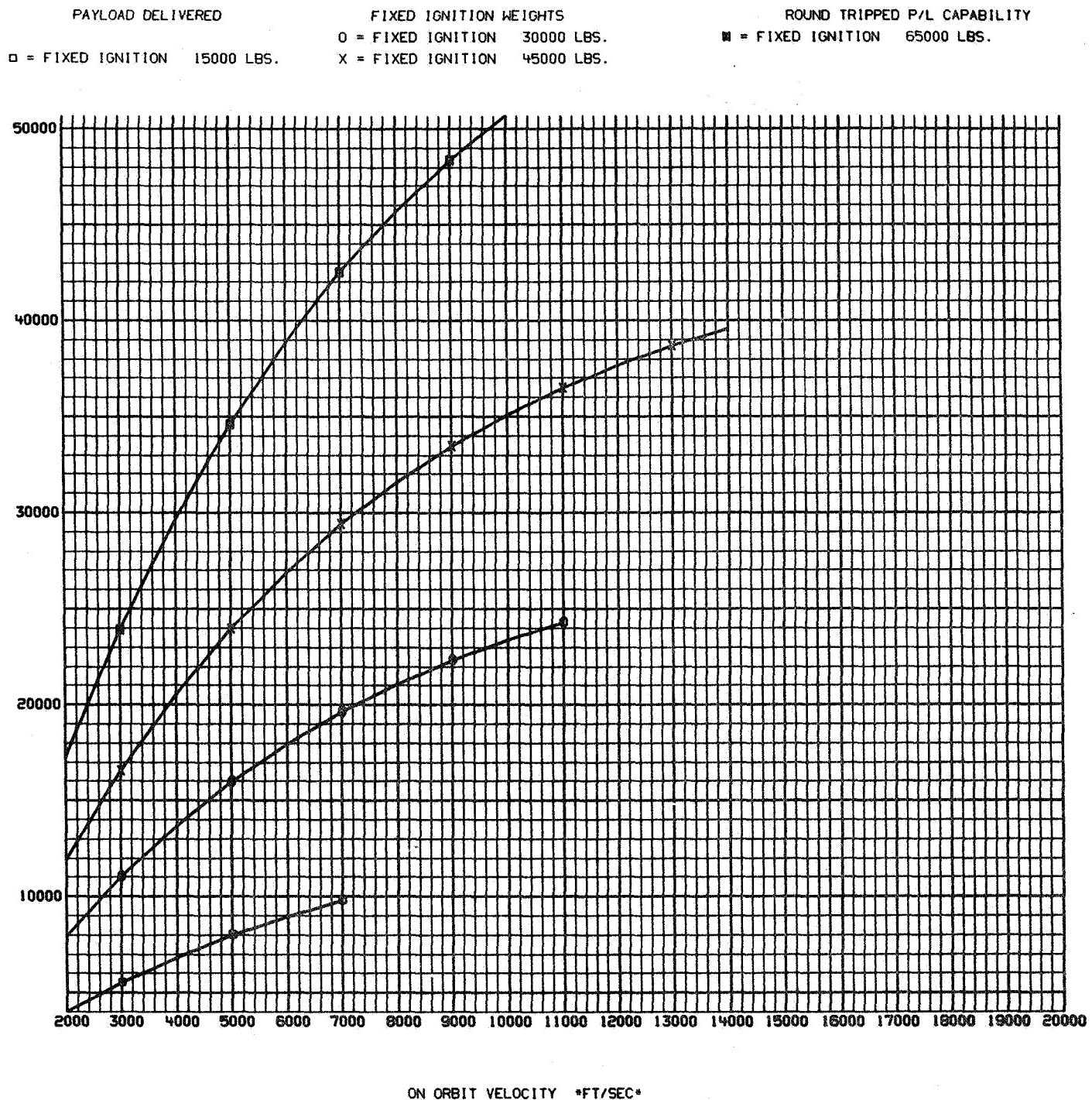


Figure 3-127

3-112

MODE 2

PAYLOAD RETURNED
• = FIXED PROPELLANT 51994 LBS.
□ = FIXED IGNITION 15000 LBS.

51994 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

TUG - P/L RETRIEVAL CAPABILITY
■ = FIXED IGNITION 65000 LBS.

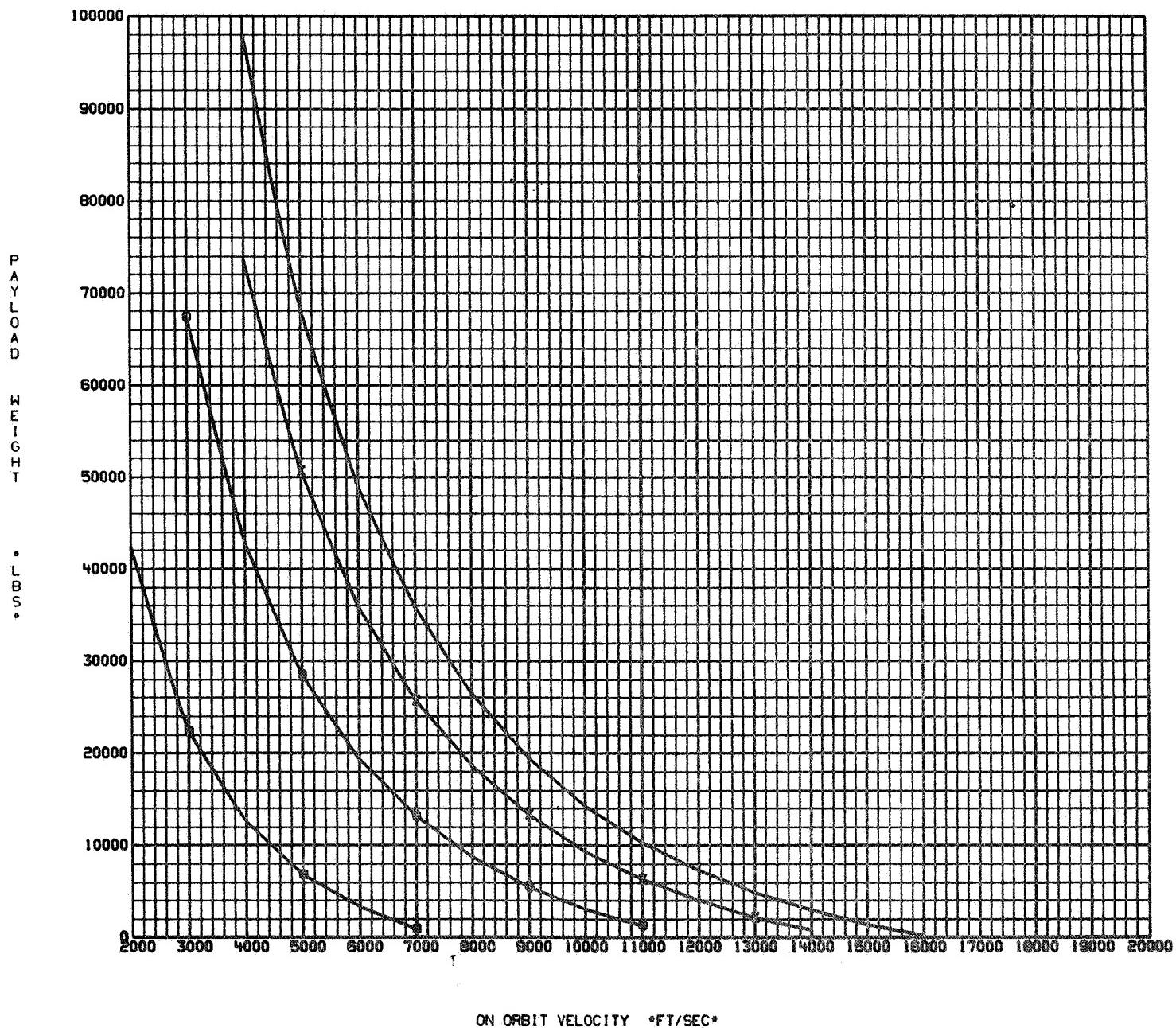


Figure 3-128

PAYOUT RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

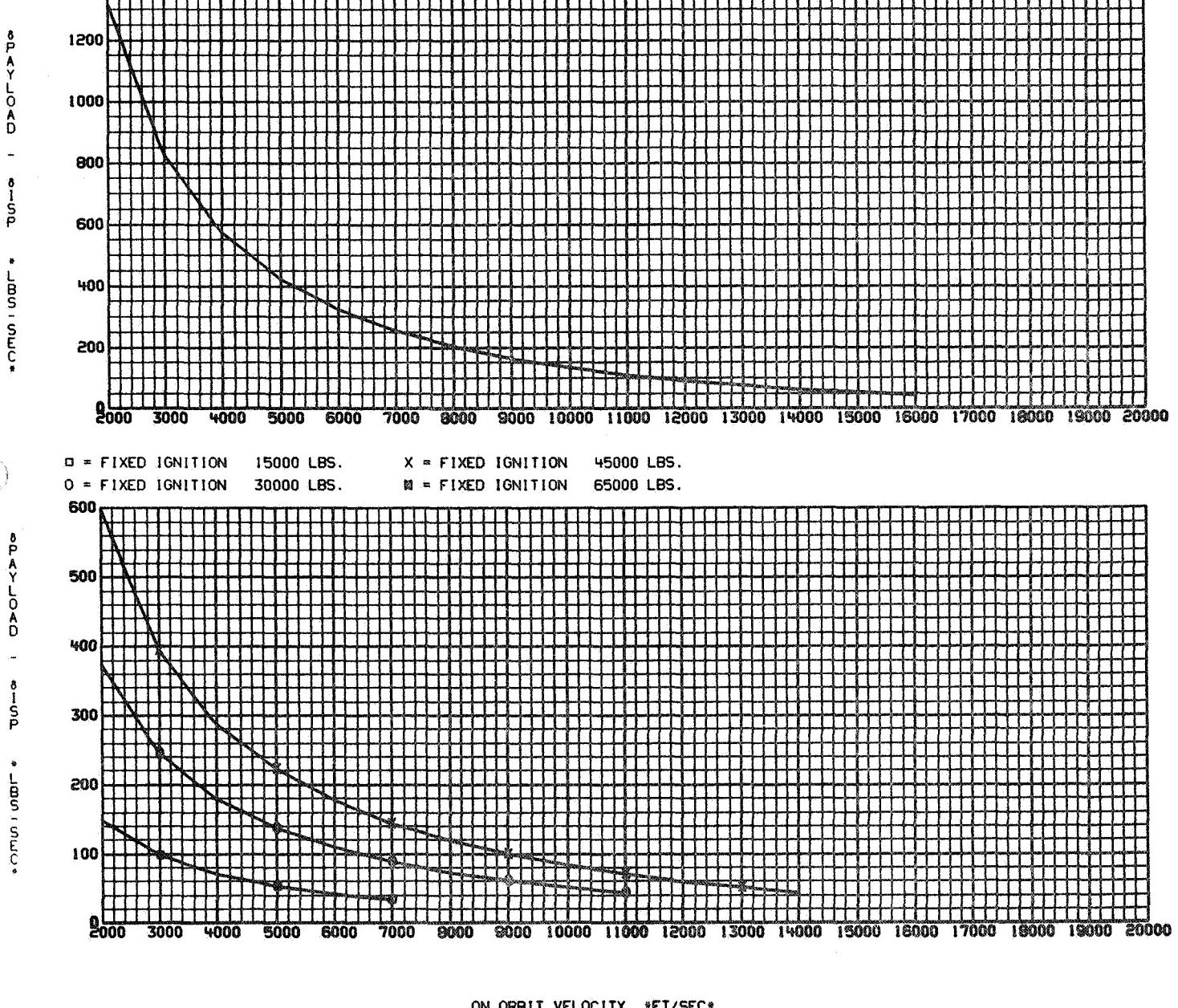
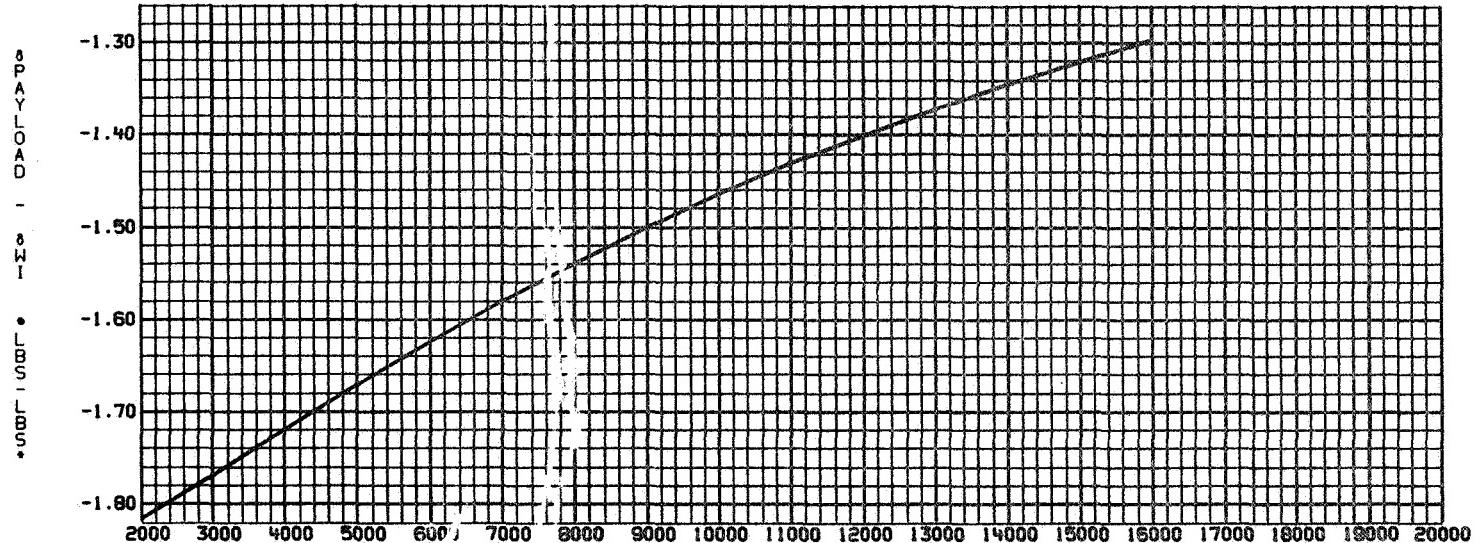


Figure 3-129

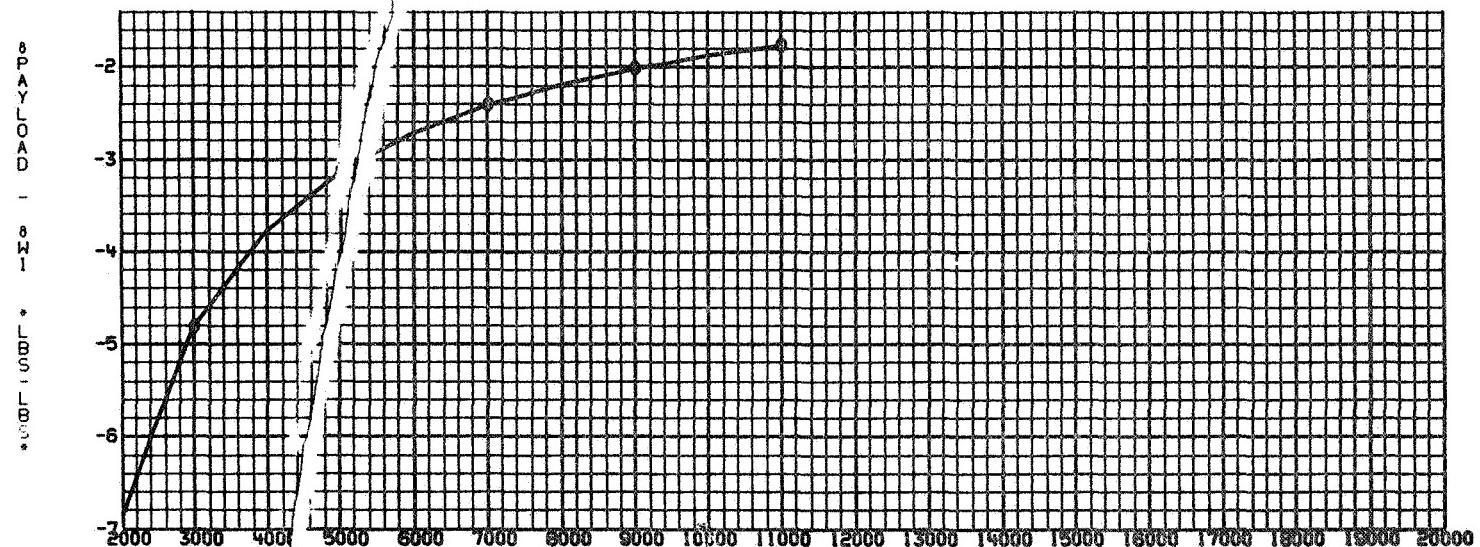
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

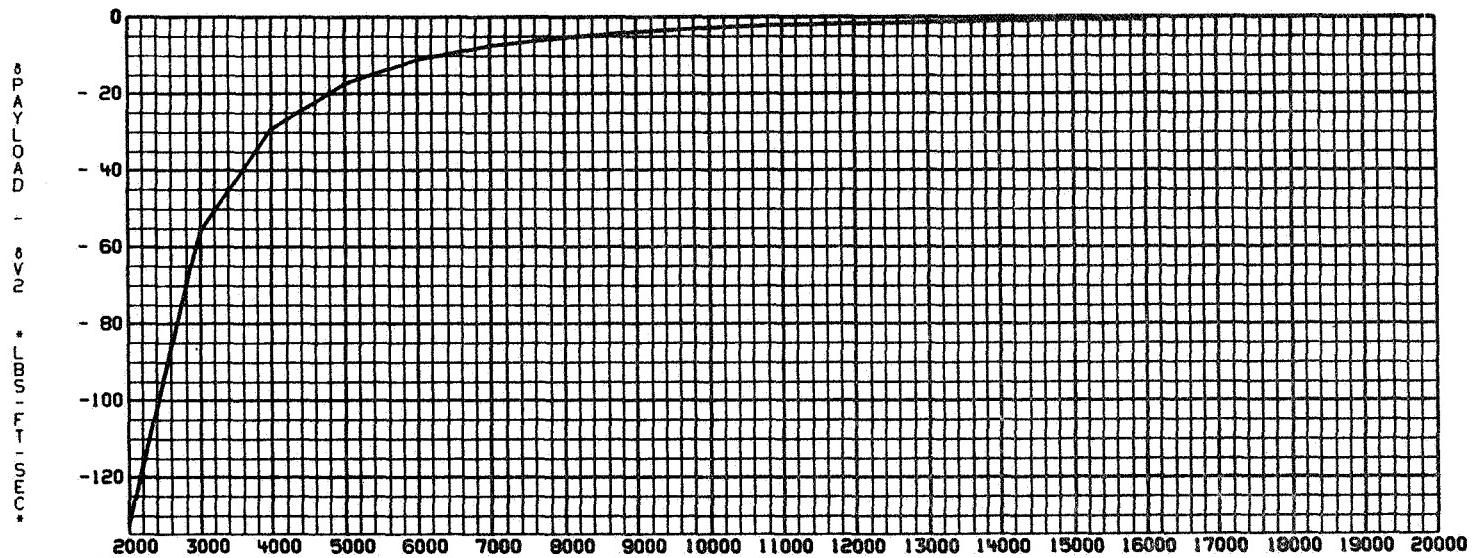
Figure 3-130

3-115

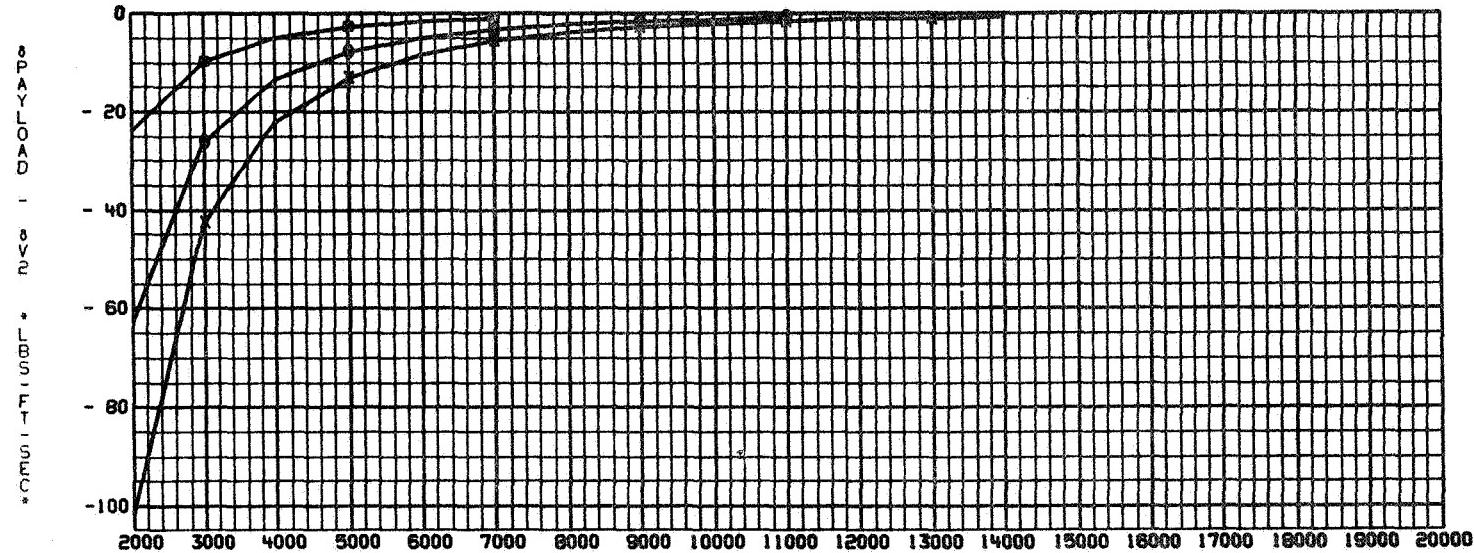
PAYOUT RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



D = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
O = FIXED IGNITION 30000 LBS. M = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-131

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

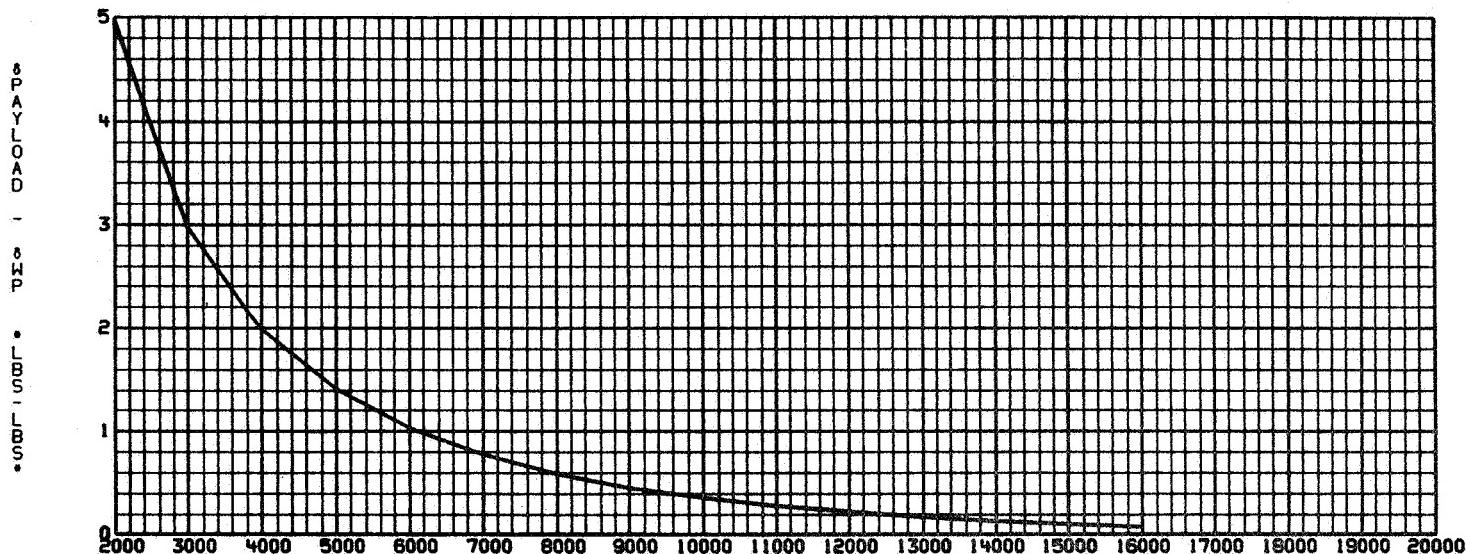
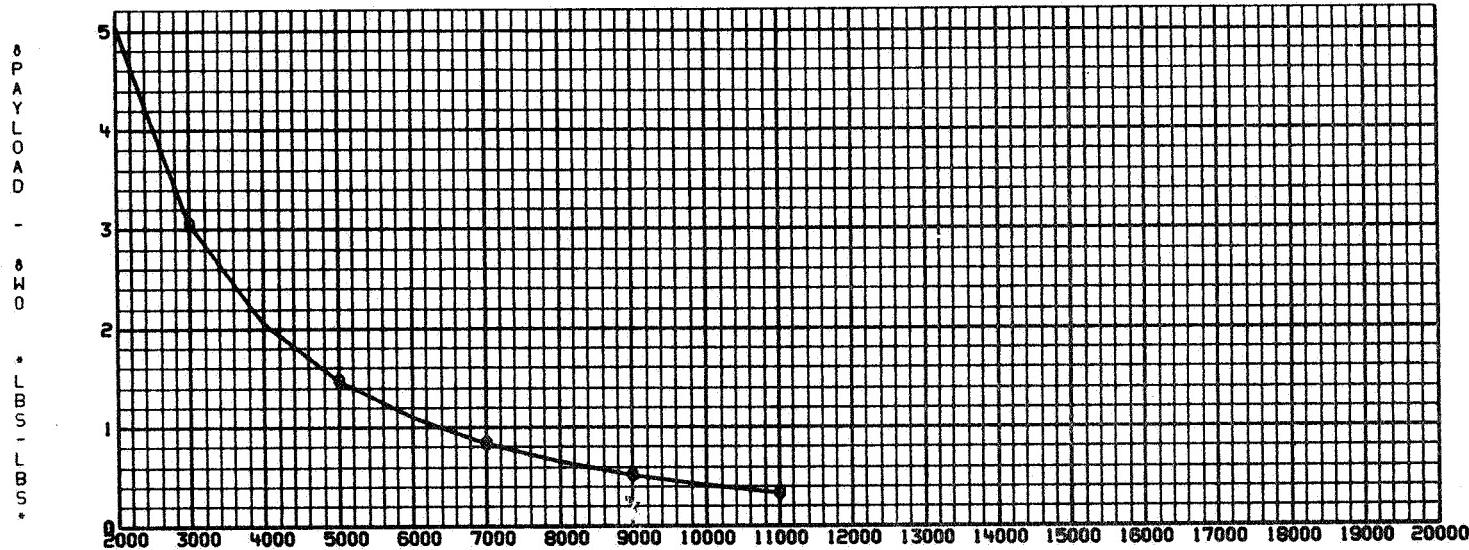


Figure 3-132

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-133

3-117

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-134

3-118

MODE 3

PAYOUT DELIVERED 51994 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE P/L ** REUSEABLE TUG
• = FIXED PROPELLANT 51994 LBS. O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.

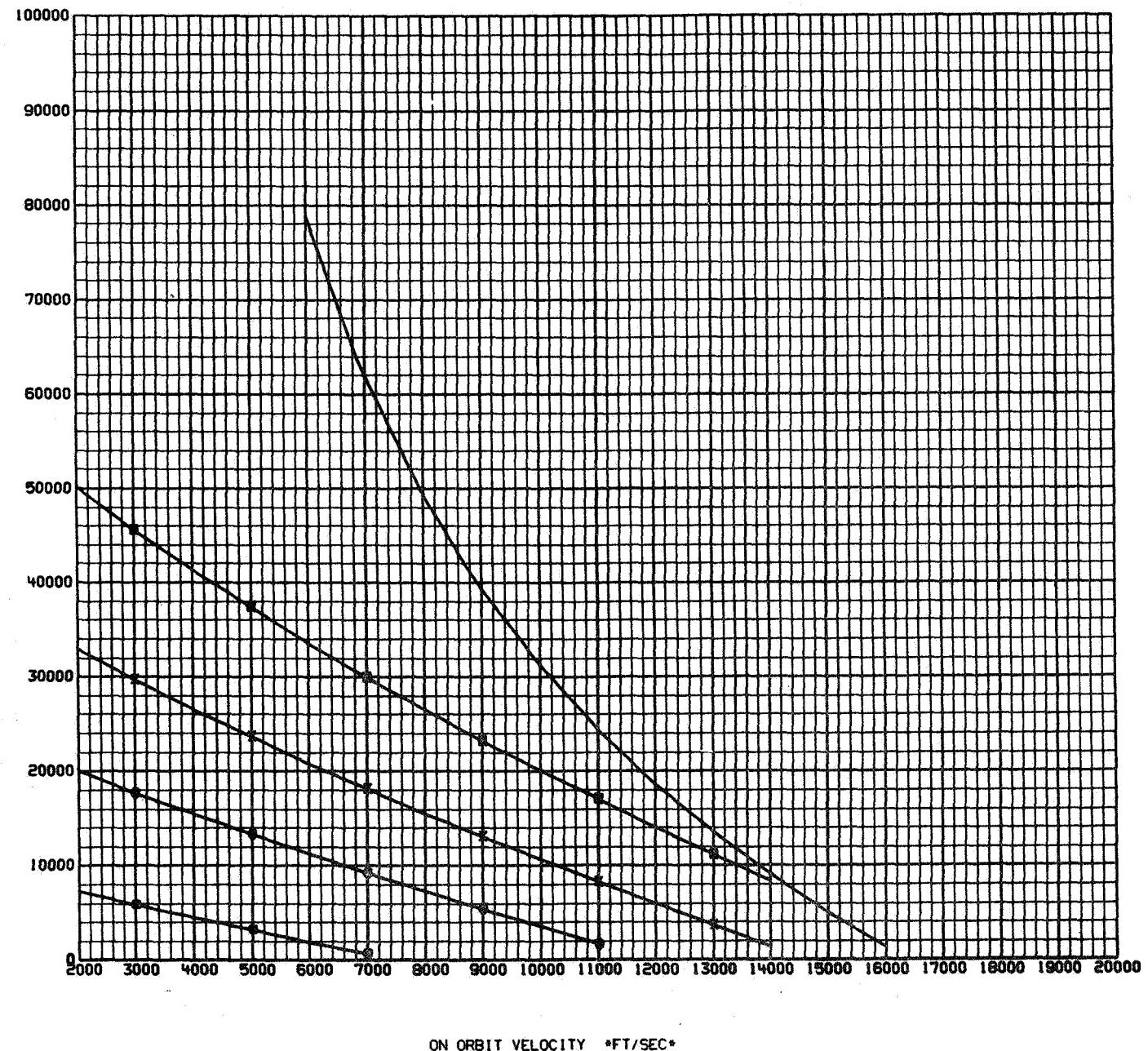


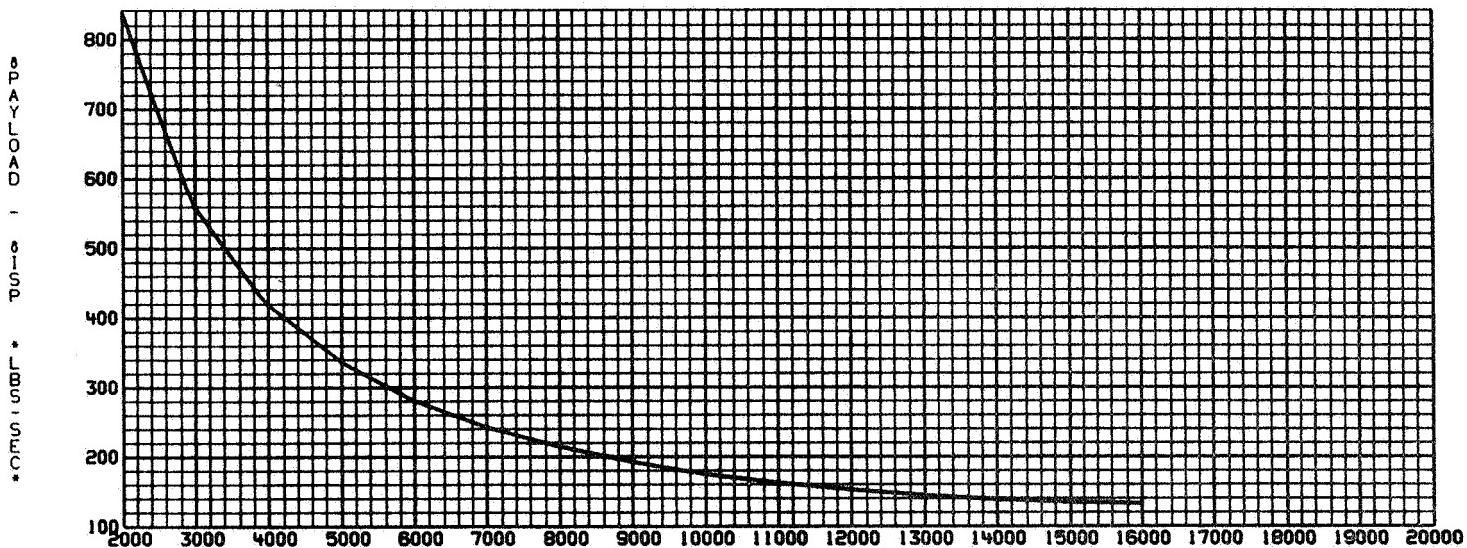
Figure 3-135

3-119

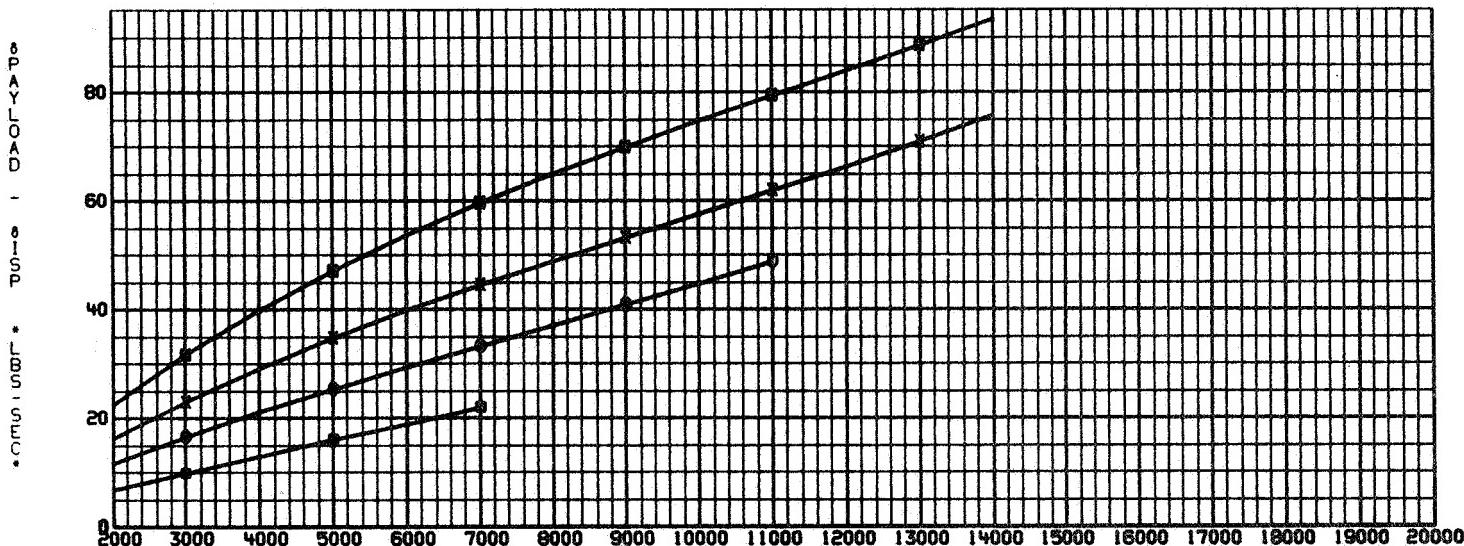
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



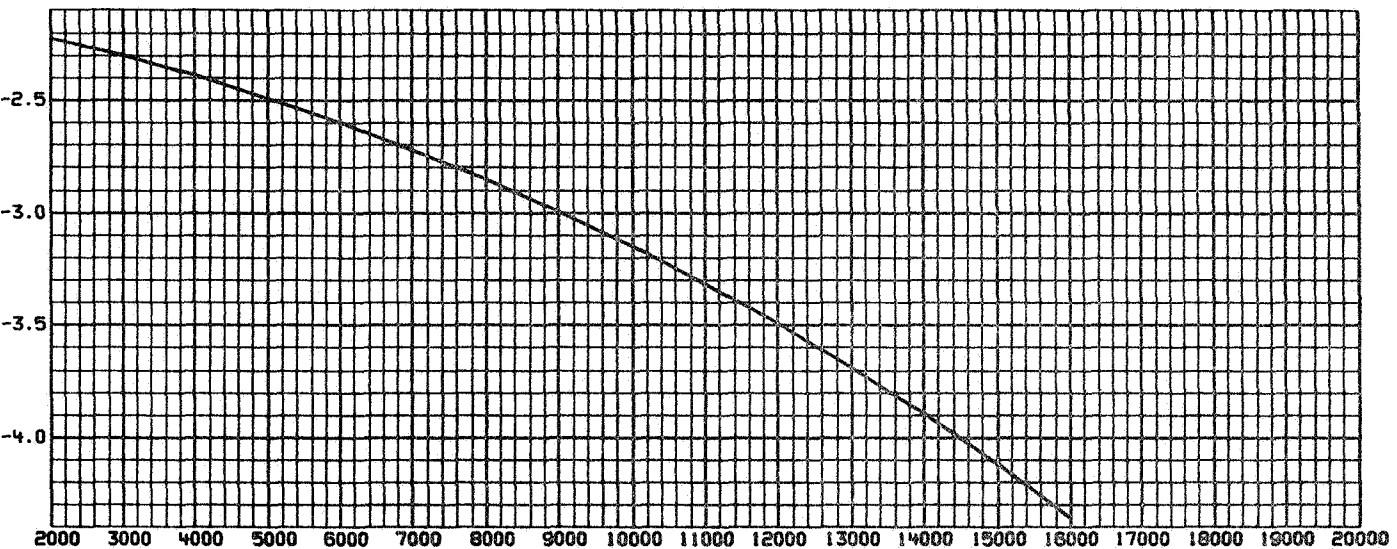
ON ORBIT VELOCITY *FT/SEC*

Figure 3-136

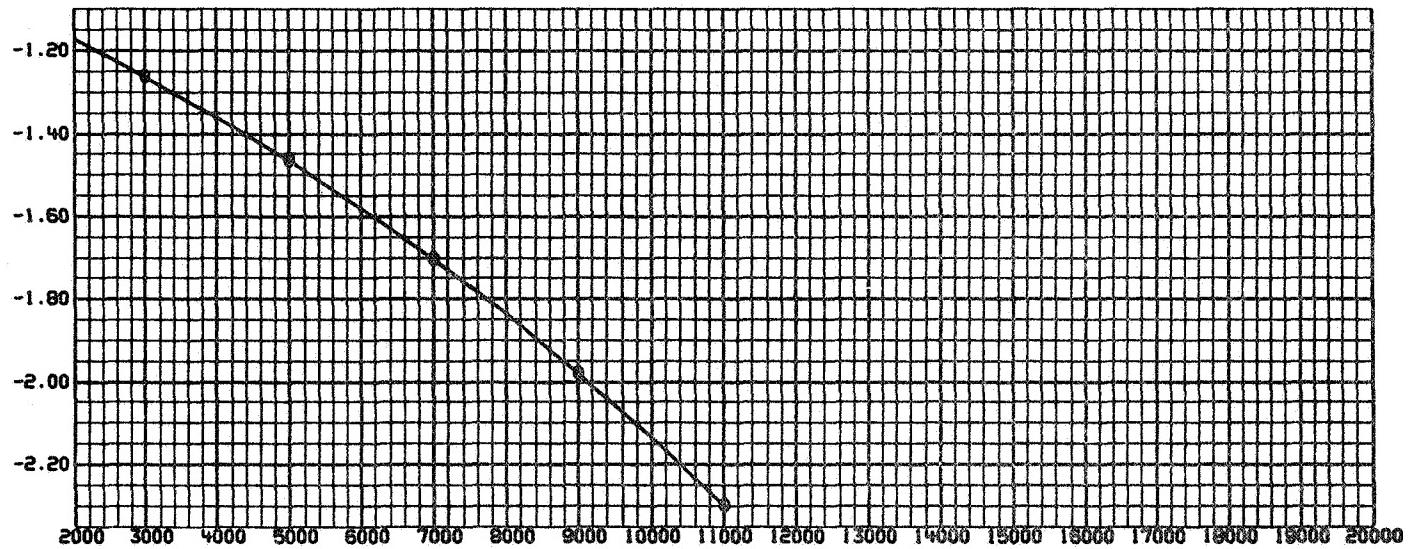
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-137

3-121

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT

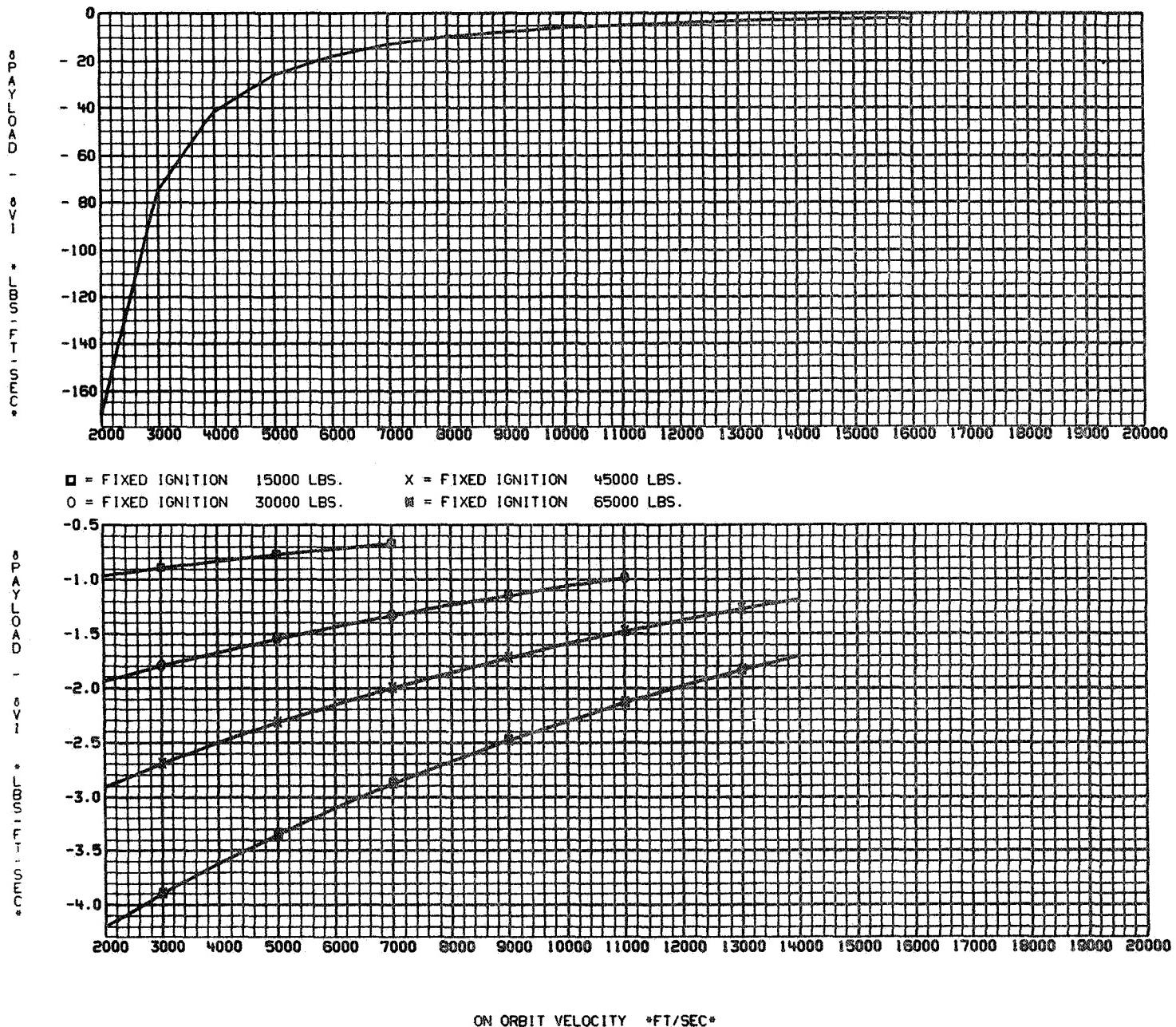


Figure 3-138

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT

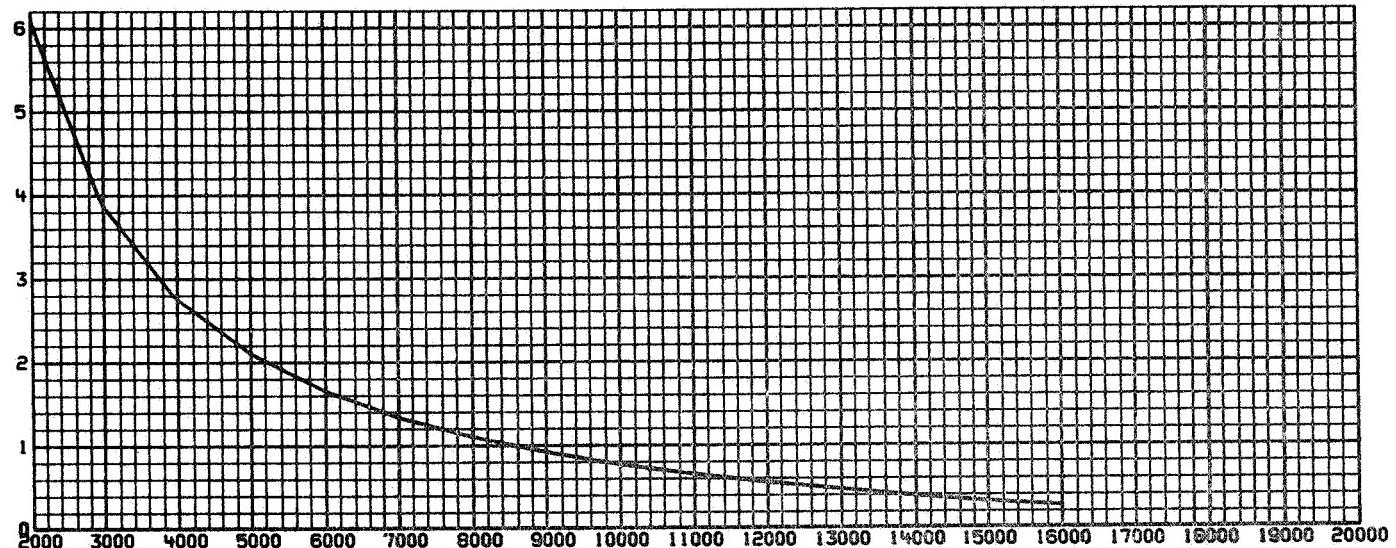
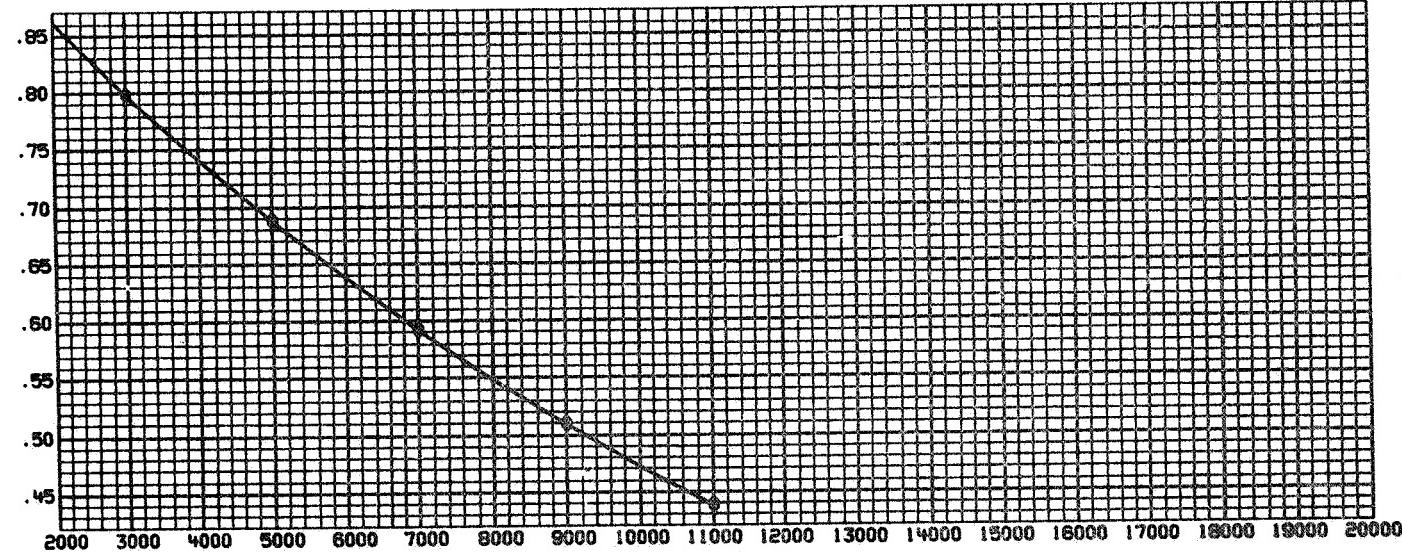


Figure 3-139

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

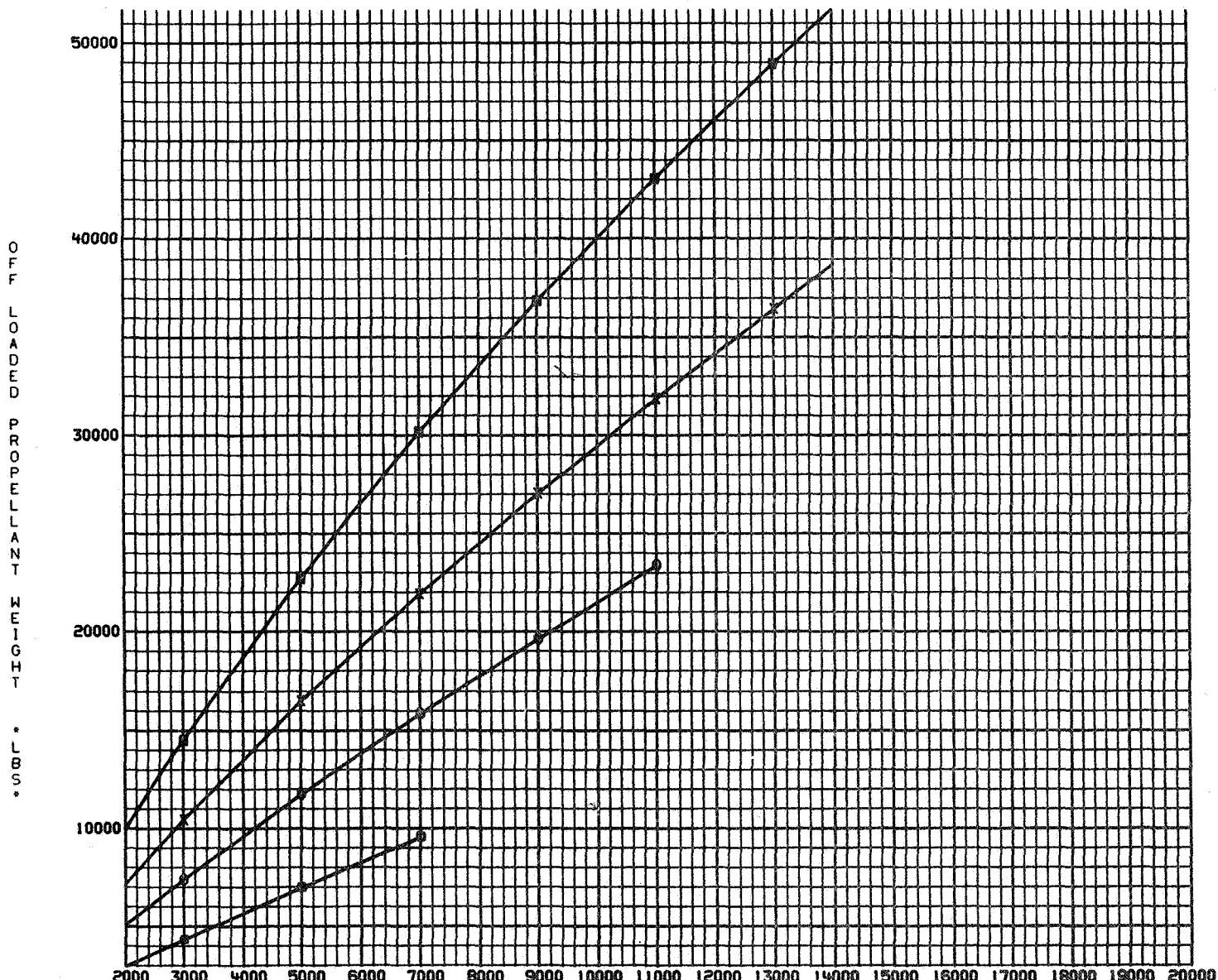
Figure 3-140

3-123

PAYOUT DELIVERED

FIXED IGNITION WEIGHTS
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE P/L ** REUSEABLE TUG
■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-141

MODE 4

PAYLOAD DELIVERED
• = FIXED PROPELLANT 51994 LBS.
□ = FIXED IGNITION 15000 LBS.

51994 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

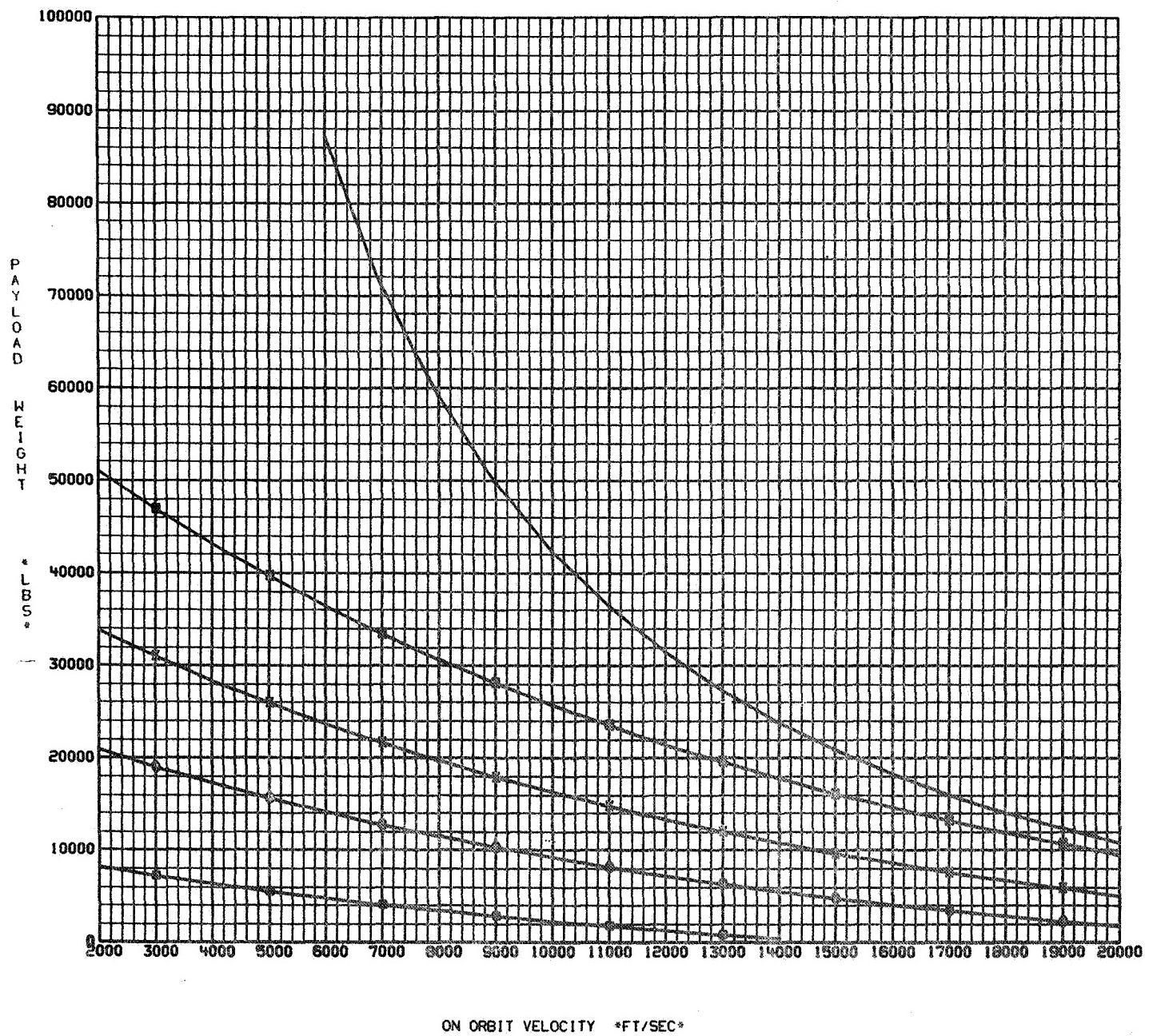
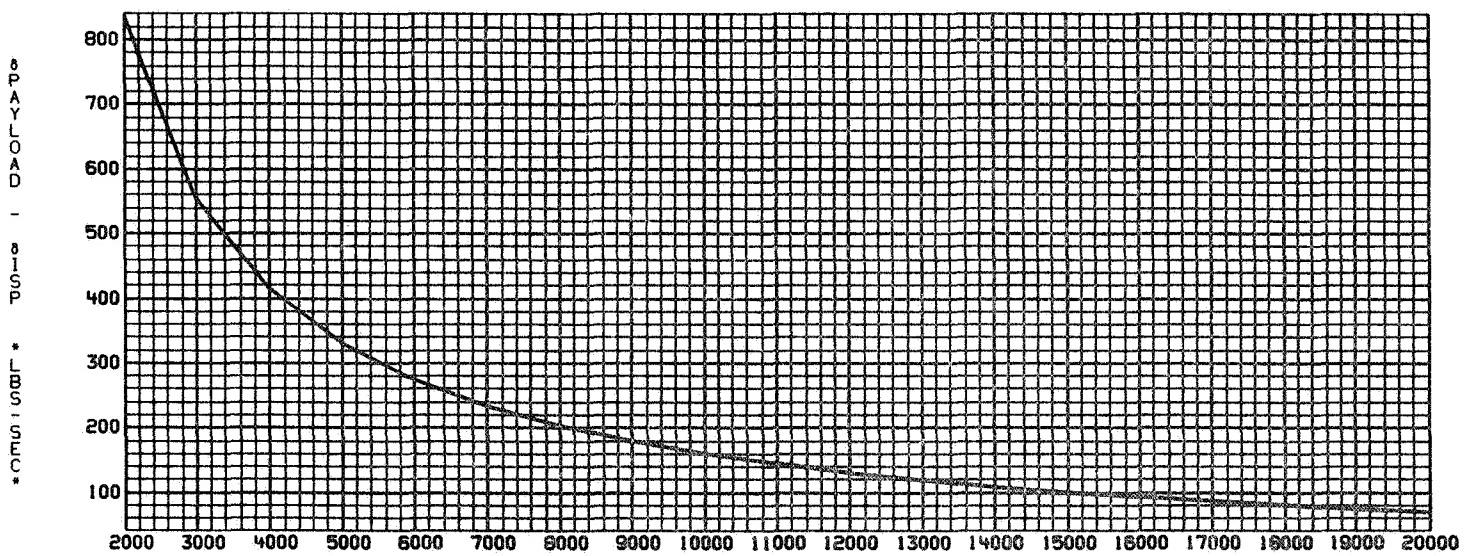


Figure 3-142

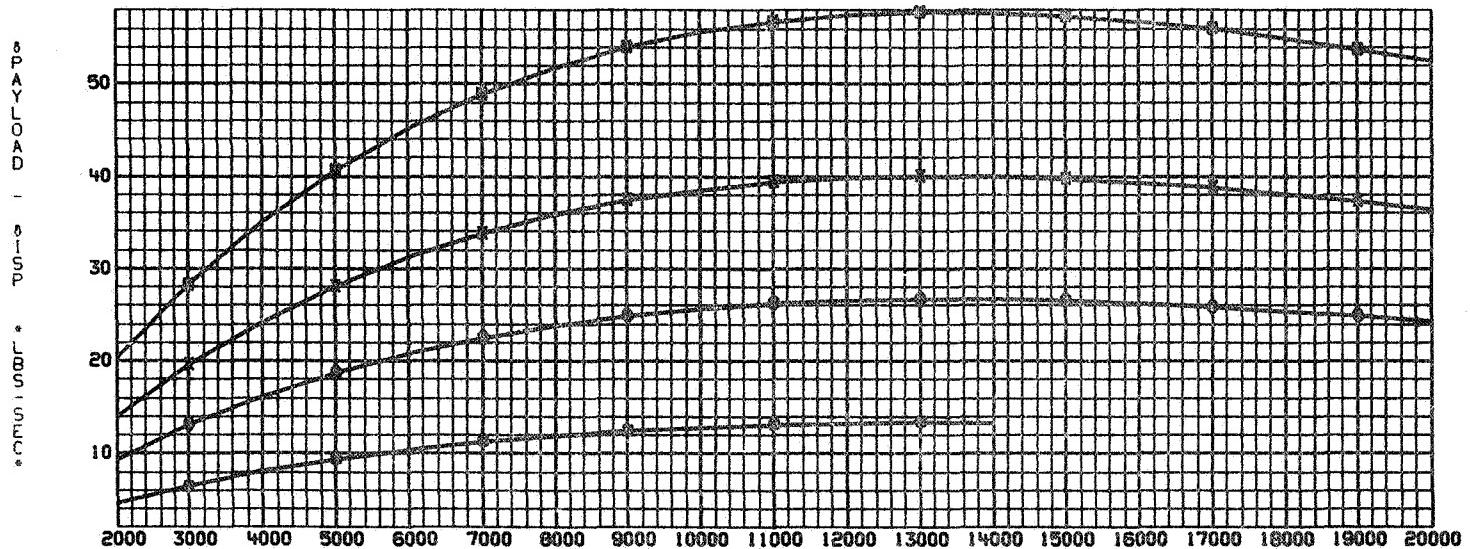
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



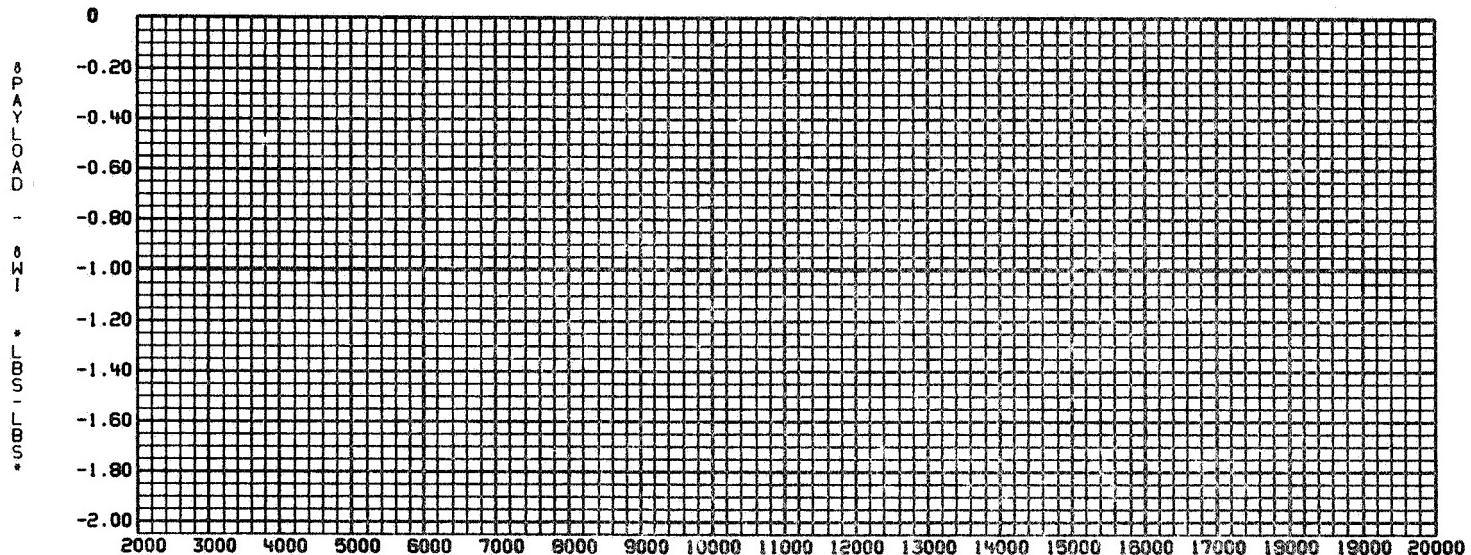
ON ORBIT VELOCITY *FT/SEC*

Figure 3-143

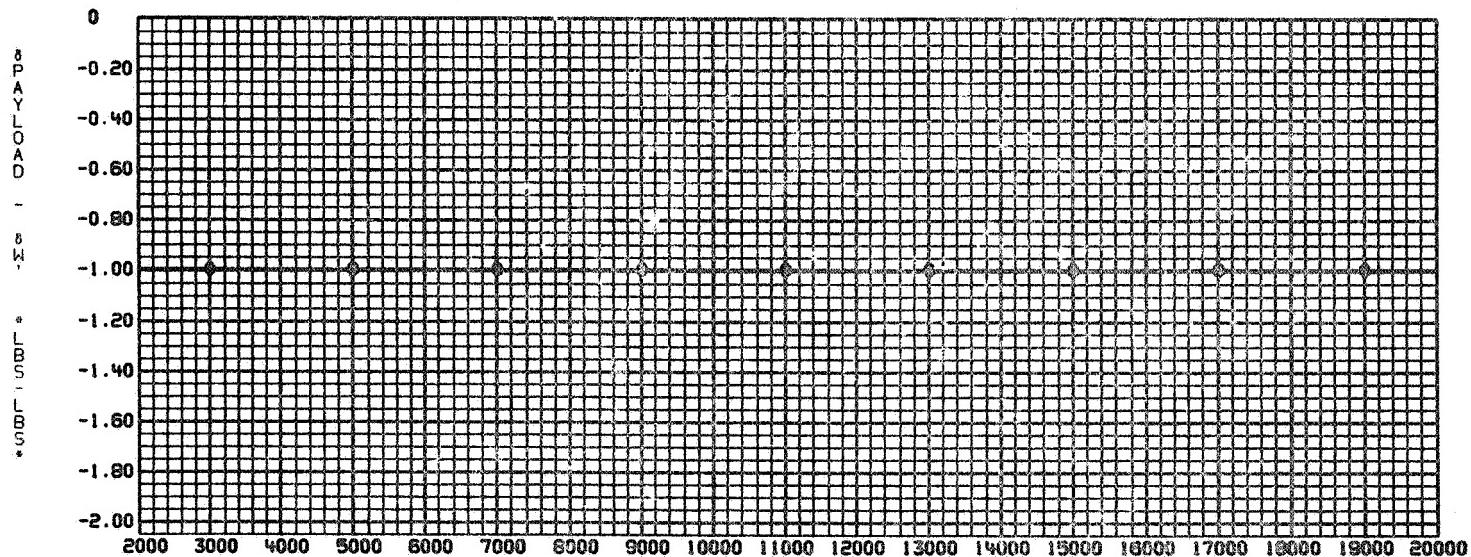
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



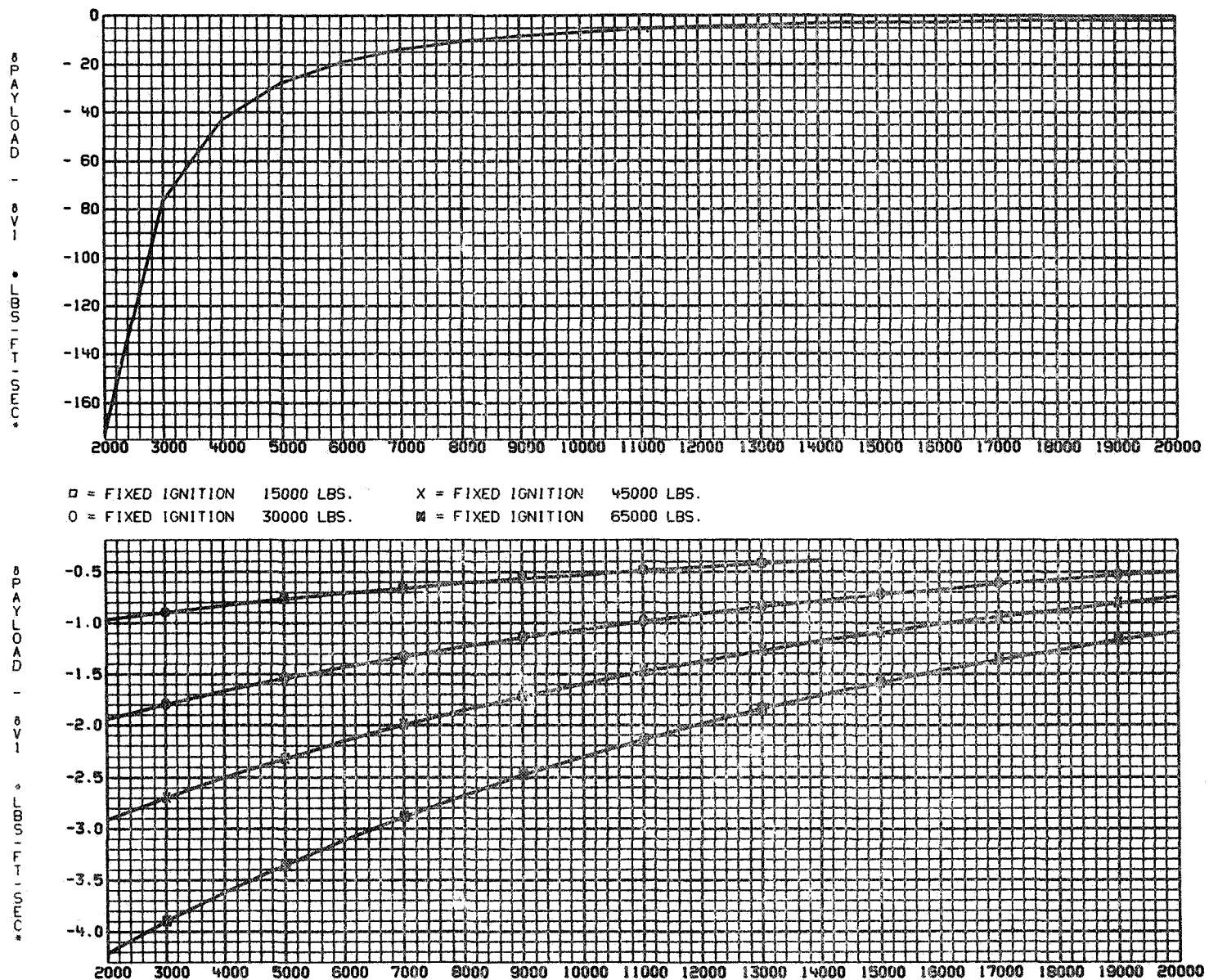
ON ORBIT VELOCITY *FT/SEC*

Figure 3-144

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT



ON ORBIT VELOCITY *FT/SEC*

Figure 3-145

3-128

PAYLOAD DELIVERED
51994 LBS. FIXED PROPELLANT WEIGHT
EXPENDABLE TUG AND P/L

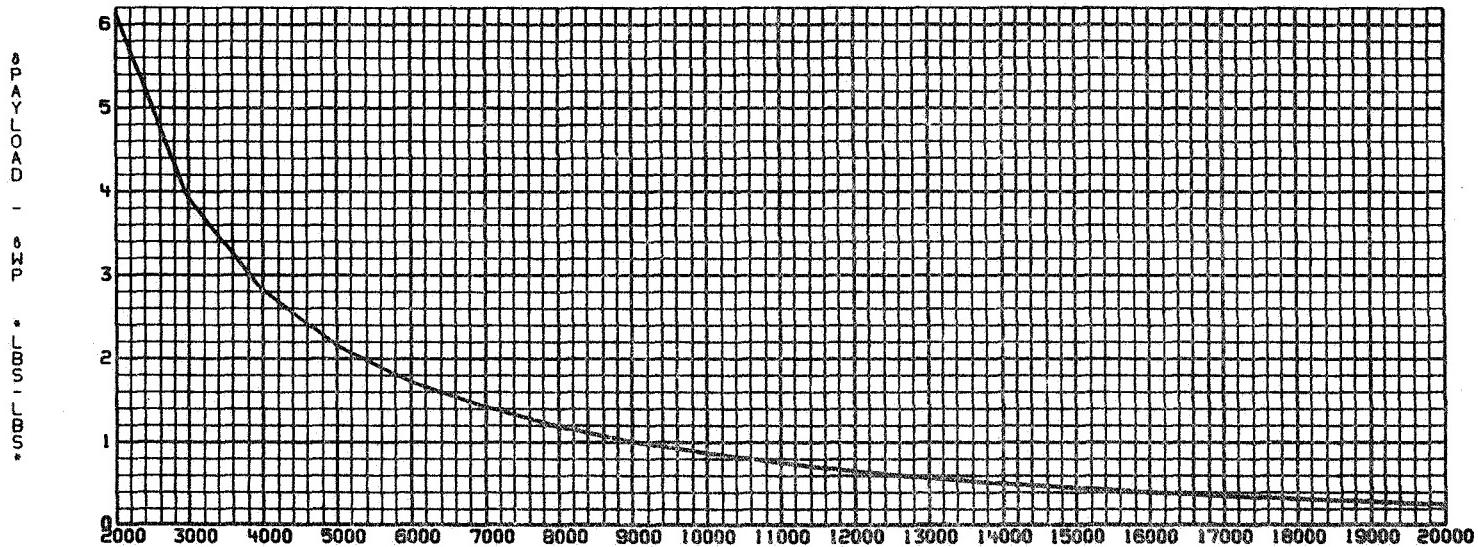
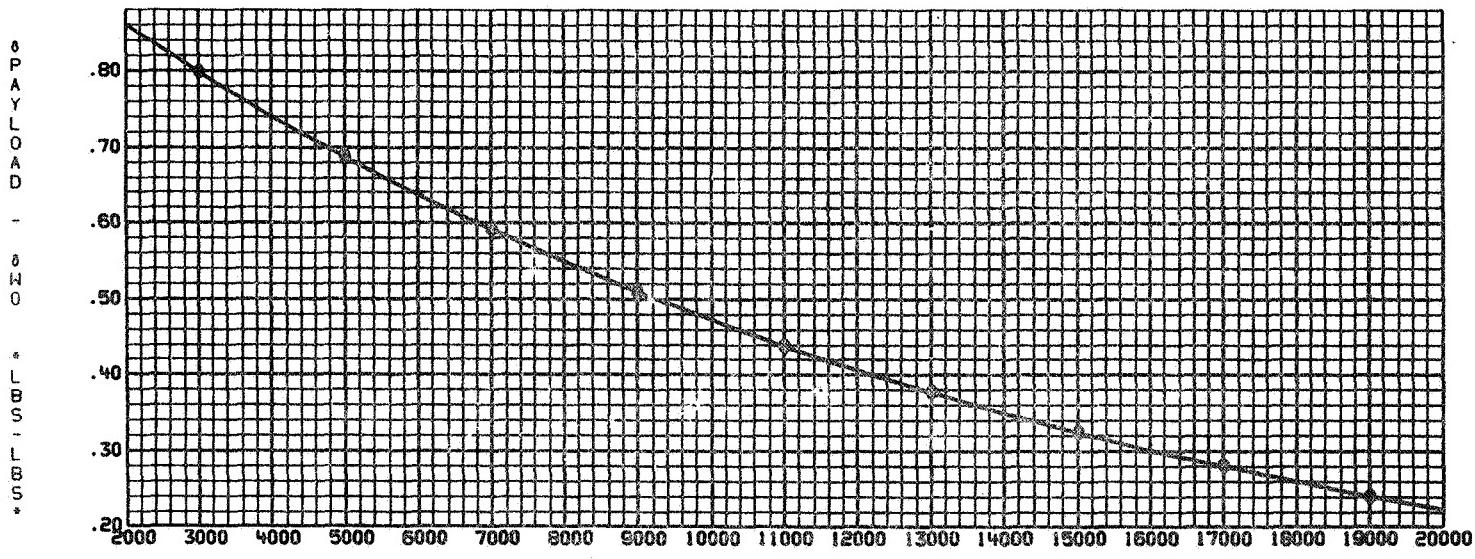


Figure 3-146

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-147

3-129

PAYLOAD DELIVERED

□ = FIXED IGNITION 15000 LBS.

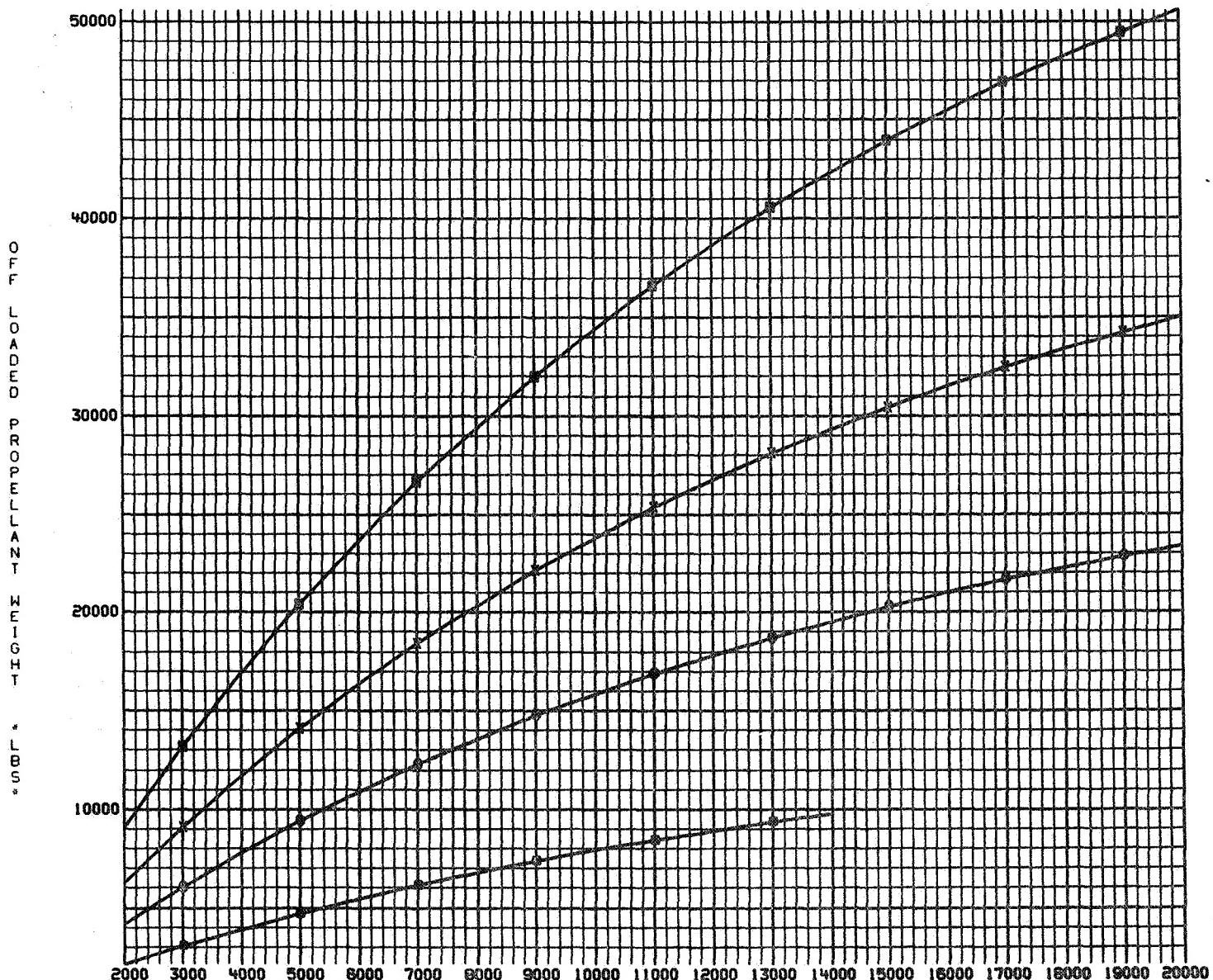
FIXED IGNITION WEIGHTS

○ = FIXED IGNITION 30000 LBS.

X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L

■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-148